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A Simplified Method for Analysis of Clines; Geographic Variation in the Hognose Snake *Heterodon platyrhinos* Latreille[1]

RICHARD A. EDGREN

THE eastern hognose snake, *Heterodon platyrhinos* Latreille, is widely distributed throughout eastern United States south of Canada. Geographic variation in *H. platyrhinos* and the two other recent species (*H. nasicus* and *H. simus*) was discussed and various conclusions have been summarized in a series of papers (Edgren, 1952, 1953, 1957a, 1957b, 1958). Publication of the majority of the data has been withheld pending the completion of satisfying and convincing analyses. The present communication contains a detailed analysis of clinal variation in ventrals, subcaudals and dorsal blotches.

Materials and Methods

Hognose snakes were borrowed from the major American museums and private collections.[2] Approximately 1200 specimens were examined and form the basis of this study. Ventrals and subcaudals were counted in the conventional way. Dorsal blotches were counted from the first on the neck to and including the one over the vent. Blotches divided into two laterally placed spots were counted as one; Y- and V-shaped blotches were considered as one when single and two when double in the mid-dorsal line.

Results and Discussion

Hognose snakes from the northern portion of the range had higher dorsal blotch counts than those from the south, although melanism and poor preservation reduced the numbers of statistics for analysis. Ventral plates also showed geographic variation, being highest in the west central and central portions of the range. Both traits are sexually dimorphic, which roughly halved comparable counts for study.

Initially, five north-south lines were drawn on a map of the eastern United States and seven lines were drawn radiating from eastern Kansas (Edgren, 1952). These lines were used as guides and data on snakes from areas crossed by the lines were pooled, analyzed statistically and plotted on another map. The five north-south lines were used in the study of the dorsal blotches and the seven radiating lines for the ventral plate analysis. The geographic patterns were interpreted as variation gradients or clines. An attempt then was made to map isophenes (Womble, 1951), regions of equivalent morphological expression of a trait. These isophenes, although probably reasonably accurate, depended upon a subjective merging of the data for the males and females, which had been analyzed separately. Also the positions of the original lines depended upon initial impressions, and therefore, largely biased the results; this was particularly true for the analyses of the ventral plates. The subcaudal scales were examined only along the two longest lines used for the ventrals, i.e., those that extended from Kansas to the extreme northeast and southeast. Subcaudal counts were lower in the north than in the south, and did not appear to correlate with ventral counts.

A more objective study of this type would employ a grid that would divide the range of a species arbitrarily into sections of approximately equal size. Fortunately, the *Heterodon* analyses were based upon lines that were sufficiently close together to approximate such a grid. Modified analyses of these data follow:

Dorsal blotches.—Mean dorsal blotch counts for each sex for 36 sections of the range of *Heterodon platyrhinos* are shown in Table 1. The mean blotch counts of the sexes were correlated (Fig. 1). The relationship between these two counts was obviously linear and inspection suggested that the slope was close to one, which implied that any en-

[1]The present communication was extracted and revised from a dissertation submitted to the graduate school of Northwestern University in partial fulfilment of the requirements for the degree Doctor of Philosophy. I am indebted to Professor Orlando Park who proposed and directed the study.

[2]Acknowledgments and lists of specimens will be included in a more extended discussion of these studies.

TABLE 1. GEOGRAPHIC VARIATION IN MEAN NUMBER OF DORSAL BLOTCHES OF *Heterodon platyrhinos* LATREILLE. CODE NUMBERS DERIVED FROM FIG. 1

Geographic Region	N	Male	N	Female	Code
Massachusetts	5	25	8	28	3
New York and northern New Jersey	35	28	25	29	4
Southern New Jersey	9	28	9	28	4
Va-Del-Ma Peninsula	8	27	13	28	4
Eastern Virginia	7	24	6	24	3
North Carolina Coastal Plain	12	22	6	23	2
South Carolina Coastal Plain	3	22	10	22	2
Southeastern Georgia	10	20	2	20	1
Northern Florida	3	19	5	22	1
North Central Florida	26	19	15	21	1
South Central Florida	5	22	6	21	1
Southern Florida	5	21	2	22	1
Dade County	11	16	5	20	1
Western Pennsylvania	12	25	5	28	3
Western West Virginia	11	24	3	25	3
Western North Carolina	12	21	8	24	2
Northwestern Georgia	5	20	3	22	1
Northern Michigan	11	27	11	29	4
Southern Michigan	14	28	19	29	4
Northern Indiana	13	26	13	27	4
Southern Indiana	13	23	19	24	2
Kentucky	6	23	6	26	3
Tennessee	2	23	9	24	2
Northern Mississippi	8	20	5	22	1
Southern Louisiana	16	20	18	21	1
Wisconsin	8	26	6	28	3
Northern Illinois	5	25	2	26	3
North Central Illinois	12	24	10	24	2
South Central Illinois	14	22	9	24	2
Eastern Missouri	6	22	5	26	3
Northeastern Arkansas	6	22	3	24	2
Western Iowa	5	22	2	23	2
Eastern Kansas	11	23	9	23	2
Oklahoma	6	22	2	22	2
Northern Texas	10	20	5	23	1
Southern Texas	5	21	7	22	1
Total	350		292		

vironmental or genetic factors that affected the female blotches affected the male blotches equally. Therefore, the regression was divided into four roughly equal segments with lines perpendicular to a regression line with a slope of one. Each segment was assigned a number from one to four that indicated increasing values. Dr. James E. Mosimann has kindly pointed out that this graphic method for coding the data is the mathematical equivalent of averaging the pairs of male and female counts and subsequently assigning code numbers to the averages. Although the graphic method is somewhat more complex than simple averaging, it permits an appraisal of the averaging process by evaluating the correlation between male and female values before assignment of the code numbers. These code numbers were plotted on a map of eastern North America (Fig. 2), and lines were drawn between values of 1 and 2, 2 and 3, and 3 and 4. This map shows that blotch counts were high in the north and northeast and low in the south. Throughout the range the blotches decreased toward the south, although this trend was most obvious in the east. In the western part of the range of *platyrhinos* the extremely high counts were absent and the intermediate values formed a broad belt.

Snakes from extreme southern Florida were distinct from material from the remainder of the range, particularly with respect to the males. It is not known whether this represents a real situation or an accident in sampling the population. Since other morphological characteristics were divergent in southern

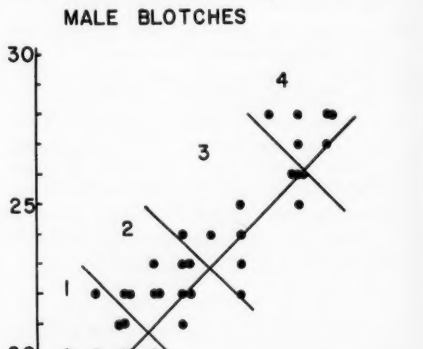

Fig. 1. Regression of mean number of dorsal blotches of male on number of blotches of female *Heterodon platyrhinos* from the "populations" designated in Table 1. The regression line was drawn arbitrarily with a slope of 1, and the distribution divided into four segments of approximately equal numbers of variants. The code numbers for the segments of the distribution are plotted on Fig. 2.

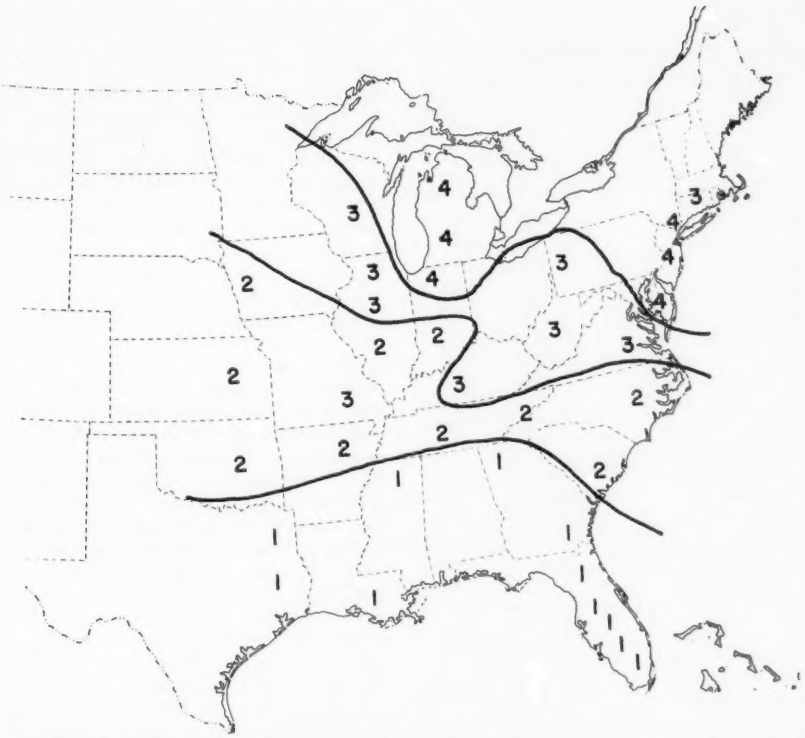

Fig. 2. The distribution of code numbers for dorsal blotches of *Heterodon platyrhinos*. Code numbers from Fig. 1 and geographic areas from Table 1.

Florida, a poorly defined entity seems indicated. This population was once known as *Heterodon platyrhinos browni* Stejneger, but it hardly seems distinct enough for further taxonomic recognition (Edgren, 1957b).

Ventral plates.—The ventral plates were analyzed by the same methods that were employed for the dorsal blotches. The mean ventral counts for forty-three samples of the species population were studied (Table 2). Again a correlation existed between male and female values, and the distribution was divided into four coded sections (Fig. 3). One point was markedly divergent from the remainder of the distribution; although that point, for western Kansas, was based upon small numbers of animals, both the males (3) and females (5) showed remarkably high ventral counts. Perhaps the west Kansas populations actually are characterized by unusually high ventral counts. Code numbers indicated that ventral counts were high in the west-central and central portions of the range of *platyrhinos* (Fig. 4). A tongue of higher counts (code 4) extended eastward from Kansas to western West Virginia, and this tongue was surrounded by a band of lower counts (code 3) that was best developed to the north, south and southeast of the high count area. Another belt (code 2) surrounded this band of high intermediate values and the extreme periphery of the range had low counts (code 1). Thus the pattern of distribution of ventrals was one of concentric rings of decreased counts surrounding a central area of high values.

Subcaudal scales.—In addition to the partial analysis presented earlier (Edgren, 1952), mean values have been calculated by state for the remainder of the range of *platyrhinos* (Table 3). Again the data were plotted on a graph (Fig. 5), which correlated the number of subcaudals in females with the number of subcaudals in males. The correlation for this trait was less convincing than that for either ventral plates or dorsal blotches. How-

TABLE 2. GEOGRAPHIC VARIATION IN MEAN NUMBER OF VENTRAL PLATES OF *Heterodon platyrhinos*. CODE NUMBERS FROM FIG. 3

Geographic Region	N	Male	N	Female	Code
Western Kansas	3	138	5	150	4
Northwestern Iowa	5	133	3	141	4
Eastern Kansas	15	133	12	141	4
Oklahoma	8	130	3	135	2
Northern Texas	9	128	3	145	4
Southern Texas	7	128	9	137	2
Eastern Iowa	6	132	8	142	4
Western Missouri	13	130	8	141	3
Eastern Missouri	5	131	8	142	4
Northeastern Arkansas	7	131	7	140	3
Western Arkansas	5	128	7	140	3
Northwestern Louisiana	5	129	3	139	3
Southeastern Louisiana	16	132	19	142	4
Wisconsin	9	128	8	140	3
Northern Illinois	5	128	3	137	2
North Central Illinois	14	129	10	140	3
South Central Illinois	18	131	12	143	4
Southern Illinois	8	131	9	142	4
Northern Mississippi	10	130	6	141	3
Northern Michigan	11	123	16	130	1
Southern Michigan	14	126	20	130	1
Northern Indiana	10	128	15	139	2
Southern Indiana	16	130	22	141	3
Kentucky	6	131	6	143	4
Tennessee	3	137	11	143	4
Southern Alabama	5	130	6	138	3
Ohio	4	128	3	140	3
Western Pennsylvania	16	128	11	138	2
Western West Virginia	12	131	3	141	4
Western South Carolina	10	128	12	141	3
Northwestern Florida	4	128	4	136	2
Massachusetts	13	122	12	133	1
New York and Northern New Jersey	34	123	26	134	1
Va-Del-Ma Peninsula	5	128	11	138	2
North Carolina Costal Plain	15	128	9	138	2
South Carolina Costal Plain	6	126	14	138	2
Northern Florida	4	124	15	136	1
North Central Florida	28	125	16	135	1
South Central Florida	5	125	6	134	1
Southern Florida	5	122	2	134	1
Dade County	12	121	5	133	1
Eastern Pennsylvania	5	124	5	139	2
Eastern West Virginia, Northern Virginia, and Maryland	23	128	22	138	2
Total	434		415		

ever, it was again assumed that there was a regression with a slope of one, and the distribution was divided into four coded sections. As suggested by the preliminary analysis, subcaudals were higher in the south than in the north (Fig. 6). The band of low intermediate values was absent through the central portion of the range, suggesting a step in the cline in this area. Since high counts seemed centered in the south and east, the distribution might be interpreted as indicating concentric rings of lower counts toward the periphery. The high values in west Kansas would not fit such an hypothesis.

Remarks on technique.—The technique of analysis presented here provides an objective method for pooling the sexes when one is dealing with a sexually dimorphic trait.

A drawback to this method is that it does not indicate statistical significance; however, the demonstration of a significant correlation between male and female values should suffice. Further the geographic continuity of similar counts obviates the need for calculated significance values. In both the ventral and dorsal blotch data such correspondence is obvious. The ventral counts for the extreme ends of the regression did not overlap (Fig. 4); the higher counts were from a continuous region in the center of the range of the species, but the low values were from discontinuous areas on the periphery. Here the continuity would seem to be one of progressive change rather than exact values. The dorsal blotch counts actually showed a geographic contiguity. It is the over-all trend that is important, not the fact that any one group might be significantly different from any other.

Some biological considerations.—The present data suggest that these geographic variations are genetic, although dorsal blotch and caudal count decreases toward the south could be phenotypic responses to warmer temperatures. Since the isophenes for the dorsal blotches run in an east-west direction, specimens from the prairies of Oklahoma and the forest areas of the Carolinas show similar expression of this trait. It is hard to believe that the environments of such divergent areas could impose similar phenotypes upon a single genotype. Thus these differences are probably genetic. This argument would seem to hold for subcaudals and ventrals. Specimens from Texas, Iowa, Virginia and western Massachusetts have similar expression of the former. Ventral counts are roughly equiv-

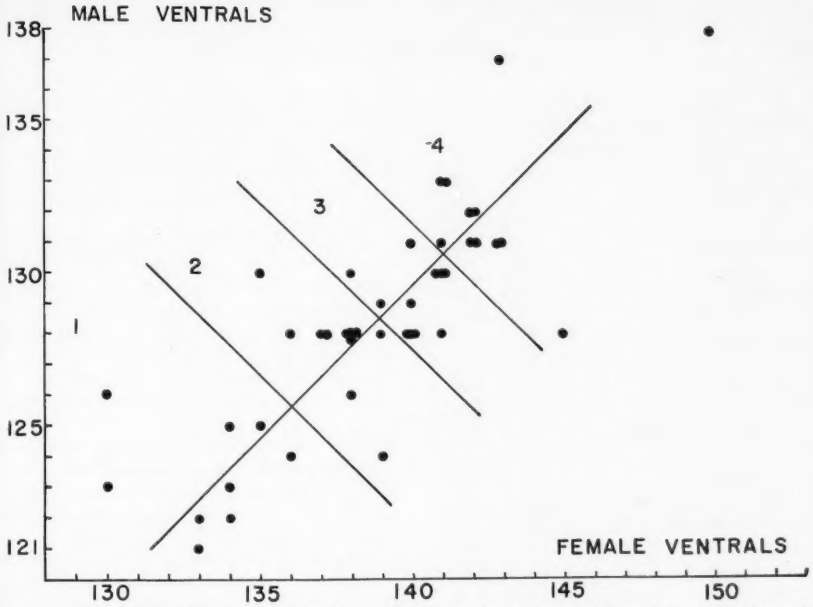

Fig. 3. Regression of mean numbers of ventral plates of male on numbers of ventrals of female *Heterodon platyrhinos* from various "populations". For details see Fig. 1 and Table 2.

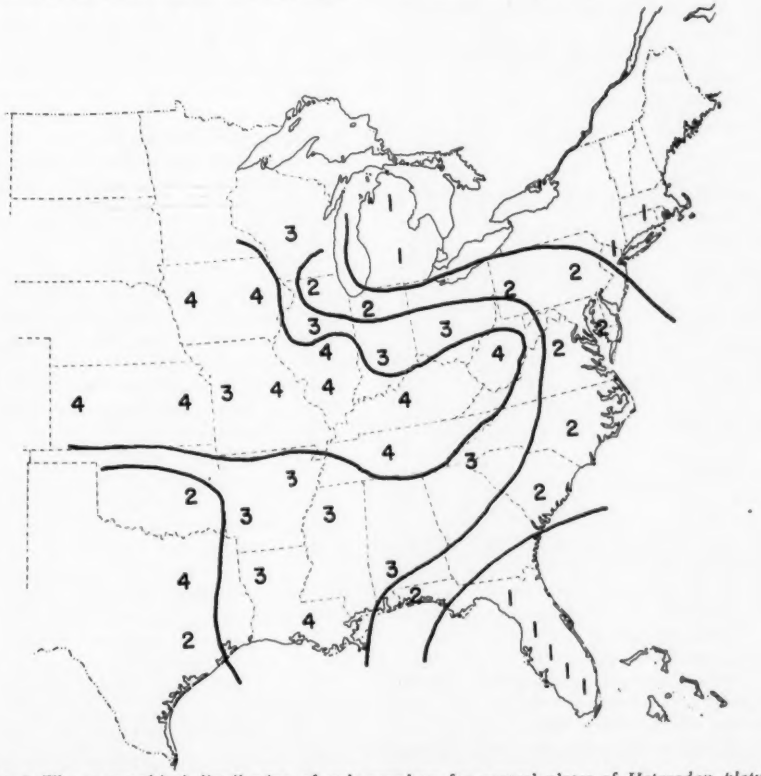

Fig. 4. The geographical distribution of code numbers for ventral plates of *Heterodon platyrhinos*. Code numbers from Fig. 3 and Table 2.

TABLE 3. GEOGRAPHIC VARIATION IN MEAN NUMBERS OF SUBCAUDAL SCALES OF *H. platyrhinos*. CODE NUMBERS FROM FIG. 5

Geographic Region	Male N	Male	Female N	Female	Code
Western Kansas	4	53	4	43	4
Eastern Kansas	15	49	12	41	1
Northeastern Arkansas	3	50	4	44	3
Northern Mississippi	10	51	6	43	3
Southwestern Alabama	5	55	6	44	4
Northwestern Florida	3	53	3	46	4
Northern Florida	4	49	6	48	4
North Central Florida	27	52	17	45	4
South Central Florida	5	52	5	42	3
Southern Florida	5	50	2	44	3
Dade County	12	52	3	45	4
Western Missouri	13	49	8	43	2
Eastern Missouri	8	45	7	43	1
North Central Illinois	14	48	10	42	1
Northern Indiana	10	48	15	42	1
Northern Ohio	3	50	1	40	1
Western Pennsylvania	15	48	11	40	1
Eastern Pennsylvania	5	48	5	44	2
New York and Northern New Jersey	36	49	25	42	2
Western Massachusetts and Connecticut	7	51	9	42	2
Eastern Massachusetts	7	48	3	42	1
Georgia	12	51	9	47	4
Iowa	9	50	5	43	2
Kentucky	5	52	5	42	3
Tennessee	3	48	10	42	1
Oklahoma	7	50	3	41	2
Wisconsin	8	49	8	40	1
Louisiana	17	52	22	44	4
Maryland	23	50	17	43	2
Michigan	34	48	42	41	1
North Carolina	23	51	11	45	4
South Carolina	14	52	21	44	4
Texas	17	49	13	42	2
Virginia	16	49	14	44	2
West Virginia	15	51	9	43	3
Total	414		351		

alent for Michigan, Florida, New Jersey, New York and Massachusetts snakes.

Thus both dorsal blotches and subcaudal scales appear to vary along clines that produce numerically high expression in the north and low in the south. These traits are probably genetically controlled, although southerly decreases in number of dorsal blotches characterize a number of species of North American snakes (Conant, 1958) and Smith (1956) has shown decreases through Illinois for a number of forms. Conditions in eastern North America appear to confer selective advantage on reduced number of blotches, or some closely related phenomena, in the south.

Variation in ventral plates appears to be a case of centrifugal speciation (Brown, 1957), with counts decreasing toward the periphery of the range from a central area of high expression. The pattern has been interpreted by Brown as the result of the migration of new genetic elements from a central area of origin. In the genus *Heterodon* evolution appears to have progressed toward a small-headed, short-bodied morphology consistent with burrowing, which suggests that the peripheral low-ventral populations of *platyrhinos* are the most highly evolved. This seems supported by the head-reduction apparent in south Florida *platyrhinos* (Edgren, 1957b). On the other hand, western populations have the highest ventral counts, which suggests the possibility of the introgression of high ventral genes from *nasicus* to *platyrhinos*. Any such introgression must have been at some remote period in the past since there is no direct evidence of hybridization among recent material. The tongue of high ventral counts in the range of *platyrhinc* falls along the southern border of the steppe that developed during the Xerothermic p- riod (see Smith, 1957, map 20). Relict di:

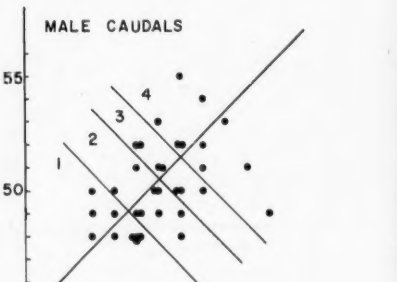

Fig. 5. Regression of mean numbers of subcaudal plates of male on numbers of plates of female *Heterodon platyrhinos* from various "populations". For details see legends for Fig. 1 and Table 3.

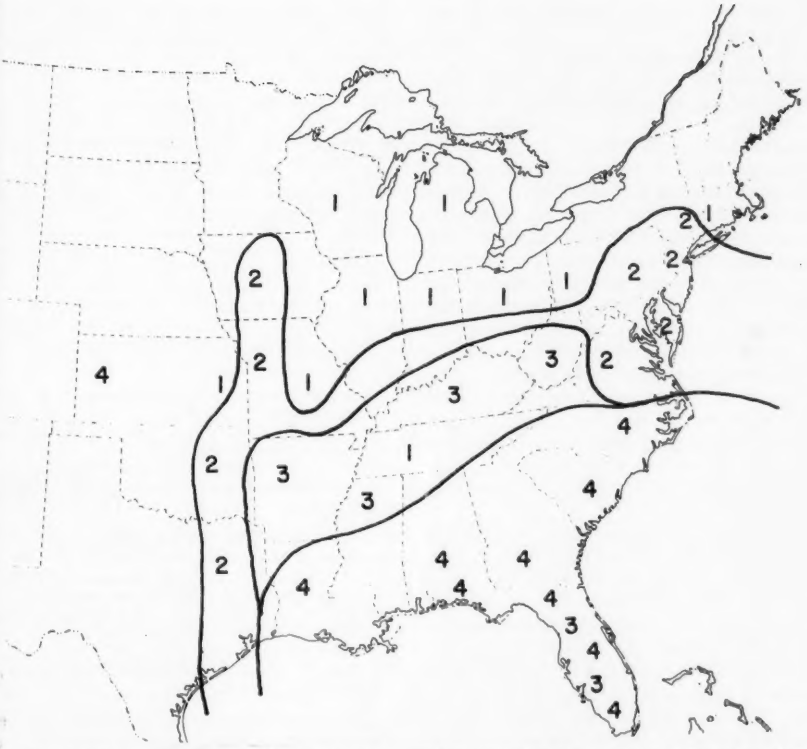

Fig. 6. The geographic distribution of code numbers for subcaudal scales of *Heterodon platyrhinos*. Code numbers from Fig. 5 and Table 3.

tributional patterns suggest that *Heterodon nasicus* had an extensive prairie peninsula distribution during the Xerothermic; thus hybridization could have occurred along the southern border of the *nasicus* range during a period when *platyrhinos* probably lived in a compressed, southeastern range.

Statistical Appendix

In order to examine the assumptions made above the data from the tables were fitted to regression curves by the method of least squares; no attempt was made to weight the individual means for variations in number of animals. In the following discussion X refers to the variable in the male and Y to the variable in the female.

With respect to the dorsal blotches, the formula for the regression line was:

$$y = 5.0 + 0.84x.$$

The slope ($b = 0.84 \pm 0.078$) was significantly different from 0 ($t = 10.769$, $p < 0.01$), but barely different from 1 ($t = 2.051$, $p \approx 0.05$). The high correlation between male and female blotches ($r = 0.88$) was highly significant ($t = 7.929$, $p < 0.01$). Thus the statistical analysis appears largely to support the actions taken intuitively above.

The analysis of the ventral plates showed similar results:

$$y = 27.0 + 0.87x.$$

The slope ($b = 0.87 \pm 0.099$) was significantly different from 0 ($t = 8.788$, $p < 0.01$), but not different from 1 ($t = 1.313$, $p > 0.05$). The correlation ($r = 0.81$) was highly significant ($t = 8.832$, $p < 0.01$). Again the above approach seems to be warranted.

As expected, the data from analyses of the subcaudal scales were not convincing:

$$y = 26.5 + 0.33x.$$

The slope ($b = 0.33 \pm 0.153$) was significantly

different from 0 ($t = 2.157$, $p < 0.05$) and from 1 ($t = 4.379$, $p < 0.01$). The correlation ($r = 0.35$) was significant ($t = 2.124$, $p < 0.05$) but the coefficient was hardly large enough to inspire confidence.

Summary

If one assumes that the environmental and genetic factors responsible for individual variability in sexually dimorphic traits affect male and female equally, it is possible to develop an index that will permit pooling the data for each of the two sexes. Such a simplified method applies code numbers to segments of a regression formed by plotting the mean ventral plate, subcaudal scale or dorsal blotch counts of male hognose snakes (*Heterodon platyrhinos* Latreille) against the counts for females from restricted portions of the range of the species. When these codes are plotted on maps they present an averaged picture of the clinal characteristics of the trait.

Snakes from the northern part of the range of *Heterodon platyrhinos* have higher dorsal blotch counts than snakes from the south. The subcaudal scales also show a more-or-less north-south cline with high expression in the north, although the correlation between the sexes for this trait is poor. Ventral plate counts are high in the western portion of the range and a tongue of high counts extends eastward across the central part of the range. Counts decrease toward the periphery from this central zone; apparently a case of centrifugal speciation.

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Research and Development Divisions, Wyeth Laboratories, Philadelphia 1, Pennsylvania

The Courtship Behavior of *Ambystoma macrodactylum croceum*

James D. Anderson

THE three major families of salamanders —Ambystomidae, Salamandridae, and Plethodontidae—have evolved elaborate courtship patterns which are rather consistent within groups of related species or genera. The behavior pattern in any group seems to be independent of the medium in which courtship occurs. *Ambystoma opacum*, for example, has a courtship pattern which is essentially identical to that of *A. maculatum*, although *opacum* is the only ambystomid known to breed on land. Noble (1931) felt that courtship behavior was conservative in evolution and thus was a useful tool in phylogenetic studies. After making a survey of courtship in several genera of plethodontids, and bringing together the literature on courtship in other groups, Noble proposed a general scheme indicating the probable course of evolution in behavior patterns within the order Urodela. He considered the mating pattern of the ambystomid salamanders as a relict and generalized behavior out of which the courtships of the "higher" families may have evolved. Noble presented convincing evidence that the patterns of the Salamandridae have arisen through an elaboration of one or more features which characterize the primitive ambystomid pattern. Plethodontids apparently evolved directly from a salamandrid stock and their courtship is a specialization of one phase of the amby-

stomid pattern, also characteristic of a primitive salamandrid group. More recent studies have verified the constancy of behavior in the plethodontids. The excellent studies of Stebbins (1949) on *Ensatina* and Organ (1958, 1960) on *Plethodon jordani metcalfi* and *P. g. glutinosus,* for example, have shown that these forms have elaborate and distinct courtship displays which are only slight modifications of the basic "plethodontid pattern" as described by Noble. The various salamandrid patterns have proven consistent within the groups as outlined by Noble.

The "primitive ambystomid pattern" that Noble considered ancestral to the behavior seen in the "higher" families was based on the courtship of *Ambystoma maculatum* and *A. tigrinum,* and later, A. *opacum* (Noble and Brady, 1933). This pattern, from which all others are supposedly derived, consists of "elaborate rubbing movements directed towards stimulating the female to the point where she will pick up a spermatophore." It is frequently a mass courtship (*maculatum* and *tigrinum*) with hundreds of individuals milling about in the "Liebesspiel." Males randomly rub females on both dorsal and ventral surfaces; vigorous rubbing might best be considered butting, females being pushed several inches off the bottom by attentive males. Females often take an active part in the Liebesspiel, nosing and rubbing the males. For example, I have observed female *tigrinum* pushing males to the surface of the water with their snouts. During the height of activity males begin to deposit spermatophores on the bottom. *Ambystoma maculatum* will deposit them in groups with or without an attendant female. When the females are sufficiently stimulated to pick up spermatophores, the substrate may be already dotted with these structures. The stimulated female may pick up a spermatophore dropped by the male who is courting her at the moment or may take another close by which had been deposited earlier.

The observations of Kumpf and Yeaton (1932) have shown that *A. jeffersonianum* departs radically from the typical ambystomid pattern, engaging in a type of amplexus occurring in certain salamandrids. Almost nothing is known of courtship behavior in other species of *Ambystoma.* Slater (1936) states that "during courtship the males of *A. macrodactylum* clasp the female just back of the forelimbs and give her peculiar short shakes; the males also clasp other small amphibians and shake them." Knudsen (1960) provides additional observations on *macrodactylum* confirming the deviant behavior suggested by Slater. However, these observations are fragmentary and require clarification. There are no other published accounts of courtship in this species.

During the course of an ecological study on *Ambystoma macrodactylum croceum,* the disjunct population in Santa Cruz County, California (Russell and Anderson, 1956), breeding adults were maintained in the laboratory for experimental studies. These captives courted throughout the breeding season. Since the published records of *macrodactylum,* although incomplete, indicate a courtship pattern unique for *Ambystoma,* an attempt was made to record the details of the entire mating sequence.

Methods

It proved impossible to make critical observations in the field because of dense vegetation and the silty nature of the water during the breeding season. All detailed observations were made in the laboratory. Adults were taken from the breeding ponds or captured as they migrated to the ponds during the breeding season. Observations were made on 11 males and 9 females in 1957, and 4 males and 3 females in 1958.

Single males were placed in aquaria (8″ x 13″ x 8″) in a totally dark, refrigerated room so that water temperatures ranged between 11.5° and 12.5° C., approximately the temperature at which courtship takes place in the field. Small stones and aquatic vegetation from the ponds simulated natural conditions. Observations, with the aid of light from a 15-watt red lamp, began when a female was introduced into a tank with a male. When not under observation the salamanders were either removed to moist finger bowls or maintained in the aquaria (as pairs) and illuminated by a 25- or 50-watt white lamp. Best results were obtained using the latter method. In the white light the animals took shelter under stones on the bottom and would resume courtship quickly when the red lamp replaced the white. Salamanders removed to finger bowls would often remain inactive for several hours when returned to the aquarium.

Behavioral Sequence

The courtship of *A. m. croceum* is strikingly similar to that described for *A. jeffersonianum.* There is no rubbing or butting phase which typifies the Liebesspiel of *maculatum,*

opacum, and *tigrinum*; rather, a direct approach to the female is followed by amplexus and an elaborate series of steps leading to spermatophore deposition and recovery (Fig. 1).

The description that follows is not the behavior of any one pair, but an average courtship. Some details and variations of the different phases will be given later. The male is usually restive, swimming along the bottom and in constant motion. The female tends to be more quiescent, remaining on the bottom and only occasionally coming to the surface for air. Immediately upon encountering a female, the male moves over her dorsal surface, his snout and chin in contact with her skin, until his snout is directly over hers. He then clasps her just behind the forelimbs with his forelimbs. In almost every instance the female swam about rapidly in an attempt to dislodge the male after this initial contact. However, once the male has attained a firm grip these avoidance movements are to no avail. The male does not engage in swimming motions unless the female persists in struggling close to the surface exposing his dorsum to the air. He will then press downward with his snout, and by quick movements of his well-developed tail drive the female to the bottom where courtship activities are resumed. The hind limbs of the male do not seem to be used either in actual courtship or for locomotion during courtship. They are characteristically held out from the body in a sprawling fashion with the soles directed posteriorly and only the inner two digits touching the substrate. Their main function seems to be in stabilizing the top heavy pair. In a single instance one male used its hind legs to caress a female in the vent region, but this was not seen in other courtships.

Once the female is restrained on the bottom the male begins a series of rubbing movements, moving his chin over her head from the midline laterally to one side and then the other. In the early stages of courtship there is a momentary pause at the midline, giving the action a jerky, halting appearance. As he rubs the female's head, the male's chin contacts the area between her eyes and nostrils and sometimes sweeps over the nostrils. Since the female still tends to struggle at this stage, the rubbing movements may be carried out with some force. The force of the movements, plus the stop at the midline, may create the impression that the male is shaking his partner. Perhaps this is the action alluded to by Slater (*op. cit.*).

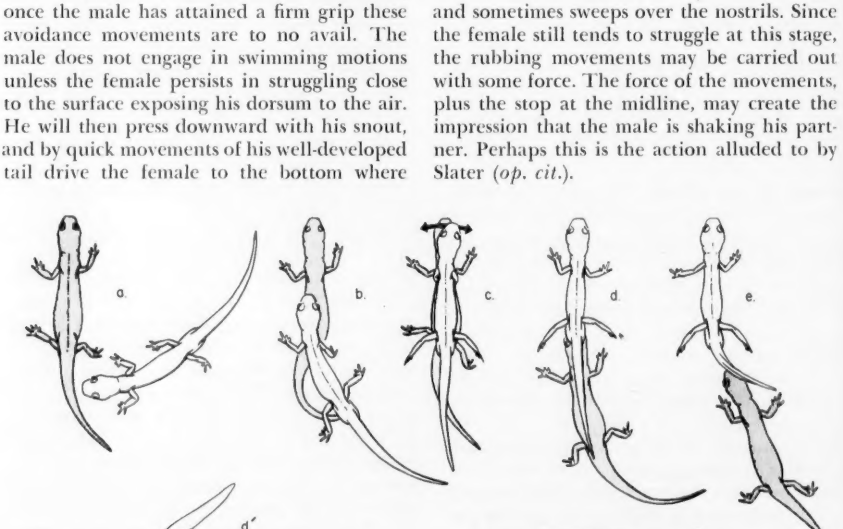

Fig. 1. Typical stages in the courtship of *A. m. croceum*. a–b. Male rapidly approaches and mounts female. c. The clasping position. Note that the hindlimbs are extended. Arrows indicate rubbing movements initiated by the male immediately after clasping. d–d′. Dorsal and lateral views as the male dismounts. The tail is held at a slight angle until the pair begins to move. e–e′. The walking sequence. The male maintains the tail at nearly a right angle throughout. f–g. Spermatophore recovery by the female. Elevation of the tail is characteristic.

Later, when the female is more subdued, some changes occur in the rubbing behavior. The tempo of movement is gradually increased and the midline stop eliminated, the movements then becoming more varied. The motion is no longer a straight, halting stroke but a smooth, sweeping arc. The male tends to use the tip and sides of his snout, in addition to the chin region, for caressing the top and sides of the female's head. Sweeps across the nostrils and tip of the snout are more frequent. If the female is quiescent the male will relax his grip slightly in order to be more effective in reaching these areas. Although the tip of the female's snout is often caressed, the motion is still essentially a lateral sweep and not an anterio-posterior movement as in *Taricha* (Smith, 1941), nor does the male open his mouth in order to use the lower jaw in rubbing as does *Taricha torosa*. Should the female resume struggling, the male will tighten his grip and return to the simple, lateral movements, generally with considerable violence.

Shortly the female becomes quiet and almost motionless. The male then slides forward over her head, coming to rest on the substrate directly in front of her, usually with his tail over her head. He will then pause momentarily and slowly raise the distal portion of his tail until it extends upward at right angles to the body axis. He next walks forward slowly with the tail tip waving slightly. The tail-waving is continued throughout the remainder of courtship and may serve to set up currents of water that probably bring the products of the male's abdominal glands to the female. If the female has been sufficiently stimulated, she will follow the male, touching her snout to the flexure point of his tail. As this contact is established the male lifts his tail even higher until it flexes just posterior to the cloaca, serving to bring the female's snout into contact with his vent region. The male continues to walk slowly over the bottom with the female in close attendance. As they walk, the tip of the male's upraised tail is curved slightly forward and held a little to one side, the distal third waved vigorously and almost constantly. Both sexes walk very stiffly with the limbs extended out from the body in a sprawling fashion. The male keeps his vent pressed firmly to the substrate and rubs it along the bottom by wave-like undulations of the pelvic region. As noted previously, the male does not use his hind limbs in locomotion at any stage of courtship, and they apparently are not utilized in pressing the vent to the substrate. The raised tail may provide some leverage for this downward pressure.

The pelvic undulations become more vigorous as they walk along. If the female is following quietly after the male he will slow down, at the same time increasing the undulations even more, and finally stop to deposit a spermatophore. The female makes no attempt to rub or stimulate the male during deposition in contrast to the behavior of the plethodontids. However, while stopped, she does rub her vent on the bottom after the fashion of the male. The undulations are strong but not as vigorous as the male's. During this interval her tail is lifted slightly off the bottom and the tip, or as much as the distal half, is slowly waved. After deposition of the spermatophore, the male, followed by the female, proceeds forward until the female's cloaca is over the pyramidal structure and then halts. The female now elevates her tail about 60° above horizontal and holds it so until she picks up the sperm packet. In one instance a female raised the tail at a right angle to the body axis exactly as its mate did. Neither animal undulates between deposition and recovery although the male sometimes begins again when the female is picking up the spermatophore and may even deposit a second at this time. However, in all observations the female departed at this time (or earlier).

Variation

The events of courtship vary and seldom was the entire sequence accomplished on the first attempt. One male was observed to clasp, dismount, and carry out the walking sequence ten times during a three hour period, not once inducing a female to follow him. He did finally deposit three spermatophores with no female present. Another male deposited fifteen spermatophores over a five-hour period, one of which was eventually accepted by a female. At least five of these were deposited without a following female. Thus, deposition does not require the presence of a female, although spermatophores are seldom deposited until the male has become stimulated by performing the entire sequence several times. Furthermore, males were never observed to deposit spermatophores without first clasping a female. Deposition of several during one walking sequence (with a female) was not unusual.

In more than 75 per cent of the sequences,

the male mounted the female from behind, the chin first contacting her in the pelvic region. The pair would then progress forward rapidly, the male keeping his chin pressed firmly to the female's back and his forelimbs tightly touching her sides. Clasping took place as the male's chin reached the top of the female's. If not, the male would shift position slightly to bring himself into an axillary grip within seconds. In this position the forelimbs encircled the female's body, the toes overlapping. Several males mounted head-on but immediately re-oriented themselves as their chins reached the females' tails. One male mounted in this fashion and clasped the female momentarily in the groin before turning around to re-align himself. Exactly what triggers the clasping reflex is not clear: either the contact of the male's chin with the female's head or the maximum body contact afforded by proper alignment. Excited males would not clasp a finger as male frogs are apt to do when first touched, nor have I seen them clasp other amphibians as described by Slater (*op. cit.*). Males were never observed clasping females anterior to the forelimbs, which suggests that the contact of the male forelimbs with the female axillary region may be important in controlling the clasping reflex. Males that were considerably smaller than females clasped them in the axillary region even though their snouts came only to the females' eyes. Courtship was unsuccessful in these cases, indicating that size of the breeding male may be an important factor. The advantages of longer heads and longer forelimbs in males are obvious.

Males were never observed to perform the walking sequence without first having clasped a female. If, for some reason, a pair became separated during the "walk," even momentarily, the male would not resume where he left off without first mounting and clasping the female. This was true even though the female was subdued and willing to follow the male without hesitation. Clasping in this case would be very brief and the "walk" soon continued. This sequential behavior is very stereotyped and consistent for the males.

The position of the female relative to the male during the "walk" was somewhat variable. They were observed with their snouts contacting the tail base, cloaca, groin or base of either hindlimb of the male. If the contacts were not in the midline the male tended to lean his upright tail in the direction opposite to the contact. Twice females were seen to butt the cloaca of males they were following, perhaps accidentally. Females were never seen to engage in any other overt stimulation of males.

Only once did a male deposit a spermatophore without lifting the tail as described and this took place after he was deserted during the walk sequence; the tail was raised less than 20° off the substrate. Occasionally males would lift their hindlimbs well above the horizontal during deposition of spermatophores; otherwise there was little variation in behavior during deposition.

Since it has been demonstrated that deposition was seldom accomplished without a walking sequence that, in turn, was always preceded by clasping, it follows that spermatophores are seldom, perhaps never, deposited without prior contact with a female. Other species of *Ambystoma* have been known to deposit them before females even reached the breeding ponds.

A male is capable of depositing numerous spermatophores. One captive deposited 15 during a 5-hour period, three in 15 minutes and two others within 80 seconds. I observed deposition of 8 of these and all were the results of clasping and walking sequences, with one deposited after each contact. A spermatophore was placed on an older one and three were laid within two inches of each other. From 15 to 30 seconds are required for deposition, once the male has halted.

Actual recovery was seen only four times. The female undulates her pelvic area while taking up the sperm packet, tail elevation occurring in all cases. The hindlimbs are held out at right angles to the body and parallel to the bottom; they are not used in transferring the sperm packet to the cloaca. Gasco (1881) stated that paedogenic *A. tigrinum* use the hindlimbs to aid in pushing the spermatophore into the cloaca. Females of *croceum* pick up the upper two-thirds of the spermatophore (sperm packet plus gelatinous neck), the basal third remaining attached to the substrate. The gelatinous portion protrudes from the cloaca, making it easy to determine whether transfer was successful.

After the basic pattern of courtship was established using one male and one female per aquarium, additional animals were employed to ascertain what effect they might have. Observations were made using the following combinations: 3 males, 2 female; 3 males, 1 female; 2 males, 2 females; 2 males, 1 female; 1 male, 2 females. There were no unusual var-

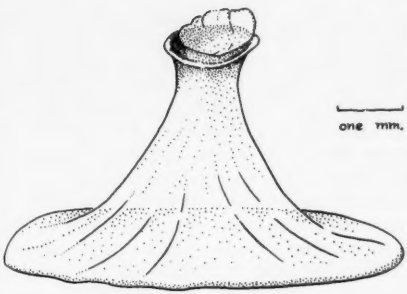

Fig. 2. The spermatophore of *A. m. croceum*.

iations and the entire sequence was observed to completion with three males and two females in a tank. The main source of variation was attributable to one or more males interfering with the activities of another male. Only once did I see a clasping male displaced by another and seldom did a male attempt to shove a clasping pair. Most interference occurred during the "walk" sequence when other males in a tank would attempt to mount a quiescent female following a male. The single female attended by three males seemed to become stimulated more quickly than others, perhaps because she was being courted constantly by one or another of these excited individuals.

There was no indication of homosexual behavior of the type noted in males of *Plethodon metcalfi* by Organ (*op. cit.*:256). However, I once observed a male attempt to dislodge a mounted male and, when unsuccessful, clasp the first male. This top-heavy group was soon broken up by the violent struggle of the original male. Otherwise there were never any mistakes in sex recognition. No aggressive behavior other than the few attempts at dislodging mounted males was noted, despite the presence of several highly excited males in the narrow confines of an aquarium.

Structure of the Spermatophore

The spermatophore of *Ambystoma macrodactylum* has never been described. It is similar to that of *A. jeffersonianum* as reported by Mohr (1931). The opaque, gelatinous base, pyramidal in shape, supports the small, white to buff sperm cap (Fig. 2). In the water the gelatinous portion transmits enough light to be invisible at a distance. The sperm cap is thus the only part visible in the water, appearing as a small whitish object suspended just off the substrate. The spermatophore, firmly attached to the substrate by a wide, oval base, tapers to a narrow, laterally compressed neck which flares slightly at the apex for holding the sperm cap (measurements given in Table 1). The apex is somewhat concave forming a cup-like depression for the sperm cap. The tapered neck probably fits the shape of the female's vent facilitating recovery since the sperm cap and most of the neck are pinched off easily by the cloacal lips. Moreover, the entire structure is laterally compressed, the long axis corresponding to the long axis (anteroposterior) of the male's cloaca; hence when deposited the spermatophore is properly oriented to match the cloaca of the female following directly behind the male.

Sperm caps seemed firmly attached to the stalk when freshly laid. They tend to lose their compactness after 20 or 30 minutes and to become smeared or detached more easily. Smith (1941) reports that the sperm capsule of *Taricha* seldom remains in place for more than 10 minutes following deposition and is easily detached at any time.

Only one spermatophore was recovered from the field. It was attached to a dead stalk of *Eleocharis* in 5 inches of water, temperature 9.8° C. Although slightly battered, it appeared identical to those deposited in captivity. In aquaria the spermatophores were attached to the bottom, on stones, leaves and plant stalks (all of the last resting on the bottom).

In size and proportions the spermatophore agrees closely with that of *A. jeffersonianum* (Mohr, 1931) but differs from those of *A. maculatum, opacum,* and *tigrinum,* these last species having larger, more truncate structures. The mode of attachment of the sperm capsule is not considered by most authors describing spermatophores of the various species.

Table 1. Measurements (mm.) of Four Spermatophores of *Ambystoma macrodactylum croceum*

	No. 1	No. 2	No. 3	No. 4
Height	3.3	6.0	5.0	8.5
Greatest diameter of base	6.2	8.5	—	10.5
Greatest diameter of neck	1.5	3.7	1.8	3.0
Height of sperm cap	0.8	3.0	0.9	3.5
Width of sperm cap	1.3	4.3	1.8	3.3

It is also difficult to determine from published accounts whether part of the gelatinous base is picked up with the spermatophore. Judging from the similar structure in *jeffersonianum*, it is probable that the attachment of the capsule and method of recovery are the same as in *macrodactylum*. This minor point may be important in interpreting some of the actions we see in courtship. For example, if a female must pinch off part of the gelatinous stalk, she would probably remain over the spermatophore for a longer time than a female removing a readily detachable cap. Such differences would necessitate different behavior on the part of the males, and the details of such behavior might be significantly distinct.

Discussion

Ambystoma macrodactylum croceum has a courtship pattern very different from that considered typical of the genus. It is, however, essentially the same as the behavior described for *Ambystoma jeffersonianum* by Kumpf and Yeaton (*op. cit.*). The sequence, at least, is identical: clasping, rubbing, and a walking sequence, followed by spermatophore deposition and recovery.

Apparently the clasping behavior of *A. jeffersonianum* is more variable. Males are reported to clasp with one forelimb anterior, the other posterior to the female's forelimbs. As the rubbing becomes more vigorous the males frequently shift their grip and place both forelimbs anterior to those of the female. The authors give no details of the rubbing behavior but the shift in clasping position is a significant difference between the species.

The behavior of the male during the walking sequence seems identical in both species as far as studied. Kumpf and Yeaton make no mention of the female lifting her tail during the "walk" or at spermatophore transfer. This lack is probably not an oversight as their observations are detailed.

As stated earlier, Noble was impressed by the constancy of behavior patterns within the salamander families and thus stressed the phylogenetic significance of courtship. Important to his phylogenetic scheme was the apparently primitive and generalized pattern known in the species of *Ambystoma* studied at that time. The observations of Kumpf and Yeaton on *A. jeffersonianum* led Noble (in Noble and Brady, 1933) to amend his appraisal of the Ambystomidae. He considered the behavior of *jeffersonianum* as a case of parallel evolution since it resembles the clasping behavior of certain salamandrids. The observations presented here on *A. macrodactylum* indicate that the courtship behavior in the genus is more variable than postulated by Noble. This variation, however, does not invalidate Noble's basic idea that the *Ambystoma* behavior pattern is possibly ancestral to those of the plethodontids and salamandrids. It must be recognized that there are at least two distinct patterns in the genus *Ambystoma* and that the clasping and specific pairing behavior pattern of *jeffersonianum* and *macrodactylum* is probably derived from the mass, rather haphazard courting and spermatophore deposition of such species as *A. tigrinum, opacum* and *maculatum*.

Until recently little was known of the relationships between the species of *Ambystoma*. Tihen (1958) has proposed several subgenera and species groupings that are useful, though tentative. He suggests a close relationship between *jeffersonianum* and *macrodactylum* on rather shaky osteologic evidence. The courtship information presented here strengthens Tihen's arrangement. It may be that courtship data will prove useful in determining relationships in this genus. Actually, few species have been investigated and the information available indicates that this approach will be fruitful.

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Summary

The courtship behavior of recently captured *Ambystoma macrodactylum croceum*, from Santa Cruz County, California, was studied during the winters of 1957 and 1958.

Ambystoma m. croceum differs from most other species of *Ambystoma* by engaging in a pectoral amplexus and an elaborate walking sequence leading to spermatophore deposition. In most respects the behavior closely resembles that of *A. jeffersonianum* and probably indicates a closer relationship between these species than between either of them and other species of *Ambystoma*. The pairing and

clasping behavior of these two species is considered as derived from the more primitive pattern known for most other members of the genus.

The spermatophore of *A. m. croceum* is similar to that of *jeffersonianum* and apparently differs only in proportions from other species of *Ambystoma*. The sperm capsule rests in a concavity at the apex of the gelatinous stalk.

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Status of the Teiid Lizards *Euspondylus strangulatus* Cope and *Euspondylus festae* Peracca

Thomas M. Uzzell, Jr.

During an attempt to determine the limits of the teiid lizard genus *Euspondylus*, it became obvious that the closely related *Euspondylus strangulatus* Cope (1868) and *Euspondylus festae* Peracca (1897) differ in many ways from other species placed in the genus, as had been noted by Cope (*op. cit.*) and by O'Shaughnessy (1881). Examination of 43 specimens of *Euspondylus strangulatus* and a study of the description of *E. festae* confirms the suggestion that they are but distantly related to members of that genus; on the other hand they show great similarity to species of *Neusticurus*.

Distribution and Variation of *Euspondylus strangulatus*

All specimens of *Euspondylus strangulatus* that I have examined are from the eastern slopes of the Ecuadorian Andes (Fig. 1). Altitude estimates for 21 specimens range from 200 to 1300 m. above sea level. With the exception of two reported from near Pallatanga, literature records for specimens not examined are also from the eastern Andean region of Ecuador (O'Shaughnessy, *ibid.*). Buckley collected the specimens from Pallatanga. Since this locality is geographically isolated from others for the species and unsupported by recent collections, it seems likely that these specimens were inaccurately labeled, as was much of the Buckley material reported from both Pallatanga and eastern Andean localities (Peters, 1955).

The original description of *Euspondylus strangulatus* appeared in a report on the reptiles and amphibians collected by an expedition led by James Orton. Orton's route crossed the eastern cordillera of the Ecuadorian Andes between Quito and Papallacta, in Napo-Pastaza (Orton, 1870). From Papallacta at about 3200 m., Orton traveled eastward along the Río Papallacta to Baeza, and then southward across the Cordillera Guacamayo to Napo on

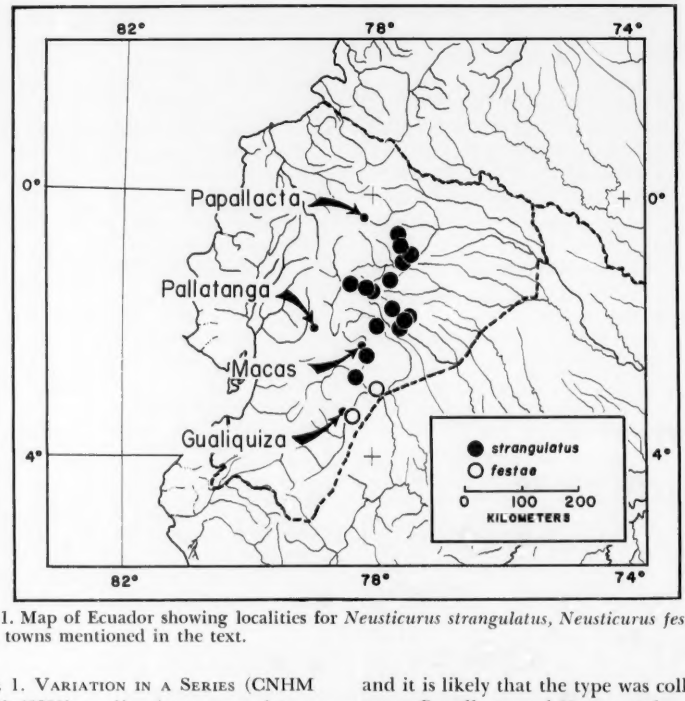

Fig. 1. Map of Ecuador showing localities for *Neusticurus strangulatus, Neusticurus festae,* and several towns mentioned in the text.

TABLE 1. VARIATION IN A SERIES (CNHM 42485–42500) OF *Neusticurus strangulatus*

	Males			Females		
	Range	Mean	Number of Specimens	Range	Mean	Number of Specimens
Dorsal scale rows	61–67	63.0	6	63–70	65.7	9
Transverse rows of ventrals	22–24	22.8	6	22–24	22.9	9
Scales around midbody	42–48	44.8	5	43–47	45.3	9
Femoral-preanal pores	50–57	53.8	6	6–12	8.3	10
Scales, posterior margin of interparietal	6–10	8.0	6	5–9	7.4	10

the Río Napo. From Napo (elevation about 500 m.), he proceeded by boat down the Río Napo to the Marañon and the Amazon. Below Papallacta, Orton's route lay in the known range of *Euspondylus strangulatus,* and it is likely that the type was collected between Papallacta and Napo, or along the Río Napo before it joins the Marañon.

The type of *Euspondylus strangulatus* is apparently lost. Cope gave no catalog number for the specimen; additional data concerning locality seem unlikely to be forthcoming.

All of the 43 specimens of *Euspondylus strangulatus* examined have 8 longitudinal rows of ventral scales and 2 scales in the posterior row of preanals. Twenty-four of the 25 males and 14 of the 18 females have 4–4 supraoculars; three females have 3–4 supraoculars, and one male and one female have 3–3 supraoculars. The loreal is in contact with the supralabials in four males and one female.

Variation in several characters of six males and 10 females (Chicago Natural History Museum 42485–42500) from southern Morona-Santiago is presented in Table 1. In this series all of the males and seven of the females have 4–4 supraoculars; two females have 3–4, and one, 3–3. None has the loreal in contact with the supralabials. Altitude data for these specimens are not available.

Altitudes of the localities for 15 males and six females with adequate data were estimated from the American Geographic Society's Map

TABLE 2. ALTITUDINAL VARIATION IN SPECIMENS OF *Neusticurus strangulatus* FROM THE DRAINAGE OF THE RÍO PASTAZA

	Males				Females			
	Altitude							
	600 m. or less		700 m. or more		600 m. or less		700 m. or more	
	Sample Size							
	3		6		2		3	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Dorsal scale rows	67–85	76.6	55–70	64.3	88–90	89.0	66–74	70.0
Transverse rows of ventrals	23–24	23.3	21–26	24.2	23	23.0	23	23.0
Scales around midbody	45–49	47.3	40–46	42.5	47–48	47.5	44	44.0
Femoral-preanal pores	54–55	54.3	45–47	46.0	6–9	7.5	6–10	8.0
Scales, posterior margin of interparietal	7–9	8.0	5–7	6.0	7–9	8.0	7–8	7.3

of Hispanic America, 1:1,000,000. The estimates are indicated in the list of specimens examined. Variation in several characters of nine males and five females from the upper and lower Río Pastaza drainage is presented in Table 2. Specimens from higher altitudes have fewer dorsal scale rows, fewer scales around the middle of the body, and fewer scales bordering the posterior margin of the interparietal than those from lower altitudes; males from higher altitudes have fewer pores in the femoral-preanal series. There are too few specimens from other drainages to demonstrate variation related to altitude, but the data are not inconsistent with those given in Table 2. Variation in specimens not included in Tables 1 and 2 is within the limits presented in those tables, except that one female has 13 pores in the femoral-preanal series, and another has only four small scales bordering the posterior margin of the interparietal.

The four males in which the loreal is in contact with the supralabials are from localities estimated to be above 700 m. Two of these are from the upper Río Pastaza drainage, and two are from southern Moruna-Santiago. Locality data for the single female with a loreolabial suture are not available.

Each of two females has a single leathery egg in each oviduct.

RELATIONSHIPS OF *Euspondylus festae*

Euspondylus festae was described on the basis of three Ecuadorian specimens collected by Enrico Festa in the valleys of the Río Zamora and the Río Santiago (Fig. 1); I know of no other specimens having the characters assigned to this form. Peters (*op. cit.*) indicates that Festa spent most of his time in what is now known as the lower valley of the Río Zamora. The syntypes of *E. festae* were almost certainly collected in Moruna-Santiago. This species, to judge by the description, shares several important characters with *E. strangulatus* (Table 3).

Euspondylus festae was said to differ from *E. strangulatus* in having fewer (35–38) scales around the midbody region, a different arrangement of preanal scales, and large, almost quadrate, dorsal scales arranged in more regular transverse rows. Peracca had no specimens of *E. strangulatus*, but the types of *E. festae* were examined by Boulenger, who had material of *E. strangulatus* available for comparison.

Cope, in his description of *E. strangulatus*, stated that there are four preanal scales, the posterior pair much larger. Peracca stated that there are two pairs of quadrangular preanal scales, the posterior pair of which are more than twice as large as the anterior and longer than wide. In the specimens I examined, two very large scales form the posterior row of preanals. Anterior to these is a row of much smaller scales, the two median of which are relatively large. Cope's and Peracca's descriptions are essentially the same; both differ from my interpretation in that neither author included the lateral scales of the anterior row in their preanal counts.

TABLE 3. COMPARISON OF *Euspondylus maculatus, Neusticurus strangulatus, N. festae,* AND OTHER SPECIES OF *Neusticurus*

Character	*E. maculatus*	*N. strangulatus* and *N. festae*	Other *Neusticurus*
Head width: neck width	slightly greater	much greater	moderately greater
Limbs	short	long	long
Tail	round	compressed	compressed
Tympanum	small, deeply recessed	large, not recessed	large, not recessed[1]
Posterior preanal scales			
Number	5–7	2	2–5
Size	none enlarged	conspicuously enlarged	when 2, conspicuously enlarged
Preanal pores	absent	present	present
Femoral-preanal pores			
♂♂	9–12	45–57	*ca.* 24–72
♀♀	9–12	6–13	*ca.* 2–8
Gular and pregular scales	flat, quadrangular	convex, round	convex, round
Granules separating gulars from pregulars	present	absent	absent
Occipital scales			
Number	2–3	4–10	3–9, usually 6 or 7
Arrangement	not radial	radial	usually radial
Temporal scales	few, large, flat	many, small, granular	many, small, granular

[1]Anterior margin hidden by reflexed ridge of scales in some species.

The dorsal scales of Cope's type are described as weakly keeled, longer than broad, rectangular, and smaller than the ventrals. The transverse rows of dorsals alternate with each other on the median line. Peracca described the scales of his types as very weakly keeled, slightly longer than broad, and quadrangular; the size is not compared with that of the ventrals. Peracca's figure of the dorsal scales shows that for at least seven rows the transverse series alternate with each other on the midline. The specimens I examined fit both descriptions equally well. Alleged differences appear to be a matter of degree and interpretation.

The only significant difference in the two descriptions is in the number of scales around the middle of the body. The range for *E. festae* (35–38) is lower than that given for *E. strangulatus* by Boulenger (1885) who examined specimens not seen by me, and lower than my counts (Tables 1 and 2). I suspect that the number of scales around the midbody region in the syntypes of *E. festae* excludes rather than includes the ventral scales, despite Peracca's statement to the contrary. Many of the specimens of *E. strangulatus* that I examined came from near the type localities of *E. festae*. It seems to me unlikely that *E. strangulatus* and *E. festae*, which are so similar in morphological details, are distinct species. Final resolution of their relationships must await reexamination of the types of *E. festae*.

I have examined the specimen referred by Burt and Myers (1942) to *Euspondylus festae* (Stanford University 8253). It is a member of the genus *Prionodactylus*, resembling *P. vertebralis* in that the frenoocular and nasal separate the loreal from the supralabials, the internasal is entire, and the two median collar scales are greatly widened; it differs from *P. vertebralis* in that the posterior median dorsal light line bifurcates shortly behind the forelimbs and continues onto the head as two light lines, passing along the superciliary scales to the snout.

GENERIC AFFINITIES

It is impractical to define or diagnose the genus *Euspondylus* because of the large number of poorly known forms included. The type species, *E. maculatus* Tschudi, a species I have examined (American Museum of Natural History 1704, 56268), differs from *strangulatus* and *festae* in several striking ways (Table 3). The conditions found in *strangulatus* and *festae* can be matched, however, in the genus *Neusticurus*. In fact, only one character serves to distinguish all *Neusticurus*

from *strangulatus* and *festae*: *Neusticurus* is presently defined as a group of at least partially tuberculate lizards, whereas neither *strangulatus* nor *festae* has tubercles.

The extent of tuberculation varies within the genus *Neusticurus*. The Ecuadorian and Peruvian form *ecpleopus*, for example, has tubercles on the back and sides of the body and tail, and on the throat, limbs, posterior part of the head and sides of the neck. Another Ecuadorian form, *cochranae*, has no tubercles on the head, throat, or sides of the body; the limbs are moderately tuberculate. *Neusticurus racenisi* Roze (1958) from Venezuela has at most a few dorsolateral tubercles on the body, although it has many on the tail. Limbs, throat, head, and neck have no tubercles, and most of the lateral and dorsal scales are uniformly small.

Considering the wide range in extent of tuberculation in other members of the genus *Neusticurus*, the gap between the condition in *strangulatus* and *festae* and that in *Neusticurus* is small. The striking similarities of *strangulatus*, *festae*, and the species of *Neusticurus* indicate that these forms should be known as *Neusticurus strangulatus* (Cope) and *Neusticurus festae* (Peracca), new combinations.

Acknowledgments.—Charles M. Bogert, American Museum of Natural History (AMNH); Robert F. Inger, Chicago Natural History Museum (CNHM); the late Margaret H. Storey, Stanford University Natural History Museum; and E. E. Williams, Museum of Comparative Zoology, Harvard College (MCZ) kindly lent me material for use in connection with this paper. Gustavo Orces-V. of the Escuela Politecnica Nacional, Ecuador (EPN) lent me specimens from his private collection (OV) as well as from the collection in his charge; this material was borrowed and brought to me by James A. Peters. James A. Böhlke, Academy of Natural Sciences of Philadelphia and Doris M. Cochran, United States National Museum, looked for the type of *Euspondylus strangulatus* in their institutions. Charles F. Walker offered many suggestions in the preparation of this paper. I wish to extend my thanks to all of these people for their assistance.

Specimens of Neusticurus strangulatus *Examined.* Ecuador: EPN 509, 4482, 6001–04; Napo-Pastaza: Abitagua (1300 m.): CNHM 26894, UMMZ 90773; Alpayaca (1100 m.): MCZ 8075–76; Loreto (600 m.): OV 1020; Mera (1000 m.): CNHM 28046; Montalvo (300 m.): OV 1191; Río Capahuari (300–400 m.): OV 1182; Río Cotopino (400 m.): UMMZ 90770; Río Napo (300 m.): UMMZ 90772; Río Oglan, upper part (600 m.): OV 3846; Río Pastaza, Canelos to Río Marañon (200–500 m.): MCZ 37262–63; Río Pucayacu (250–350 m.): OV 1112; San José de Sumaco (700–1000 m.): AMNH 28881; Moruna-Santiago: Chiguaza (900 m.): OV 1122–23, 3838, 4493; Río Yuquipa, Macas (700–1000 m.): OV 3405–06; between Río Santiago and Río Pastaza, north of Macas and south of Gualaquiza: CNHM 42485–500.

Summary

Twenty-five males and 18 females of *Euspondylus strangulatus* were examined and compared with the description of *Euspondylus festae*. Six males and 10 females from a single locality show striking sexual dimorphism only in femoral-preanal pore counts. Six males and 3 females from higher altitudes in the Río Pastaza drainage have lower scale and femoral-preanal pore counts than do 3 males and 2 females from lower altitudes; other samples are too small to show altitudinal variation.

A smaller number of scales around the middle of the body (35–38 compared to 40–49) possibly distinguishes *E. festae* from *E. strangulatus*. Many of the specimens of *E. strangulatus* examined come from near the type localities of *E. festae*. Since the two forms are otherwise very similar, it seems possible that the midbody scale counts for *E. festae* exclude the eight rows of ventrals.

Both *strangulatus* and *festae* show many differences from *Euspondylus maculatus*, the type species of *Euspondylus*, and many similarities to species of *Neusticurus*; they are therefore transferred to that genus.

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MUSEUM OF ZOOLOGY, THE UNIVERSITY OF MICHIGAN, ANN ARBOR, MICHIGAN

A New Black-headed Snake (*Tantilla*) from Southwestern Texas

M. J. FOUQUETTE, JR. AND FLOYD E. POTTER, JR.

DURING the 1959 Texas Herpetological Society field meeting at the Horace Fawcett Ranch near Del Rio, Texas, an unusual example of the snake genus *Tantilla* was collected by Mr. and Mrs. George E. Drewry. The snake was found alive, lying on a large rock sheltered by the overhang of a canyon wall, along a spring-fed tributary of Dolan Creek, which feeds the Devil's River.

The morphological characteristics of this snake differ markedly from those of any other member of this genus known from Texas. It appears to be closely related to the widespread Mexican species *T. rubra* Cope, but differs in several respects and apparently represents an undescribed form. For this species we propose the name

Tantilla diabola sp. n.

Holotype.—Texas Natural History Collection No. 24647; male. Collected at the Horace Fawcett Ranch, 37 miles north of Del Rio, Val Verde Co., Texas, March 28, 1959. No other specimens known.

Diagnosis.—Top of head black, except light snout, the black extending down to the labial border on every upper labial; a light nuchal collar, not involving tips of parietals or posterior temporals, followed by a broad black band; nuchal collar partially divided by a black trident extending posteriorly from between the parietals, involving the first two vertebral scales and the first paravertebrals. Posterior temporal elongate. Body a light tannish-gray above, fading into an immaculate

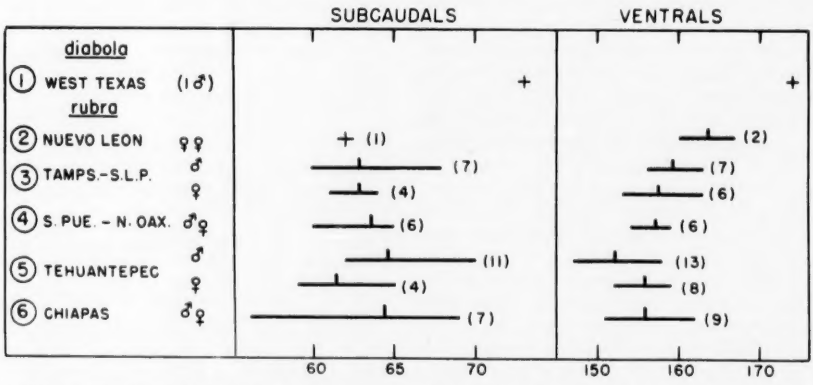

Fig. 1. Range (horizontal bar) and mean (vertical bar) in ventral and subcaudal plates of *Tantilla rubra*, as compared with counts in *T. diabola*. A + indicates the number for a single specimen. The sample size is given in parenthesis.

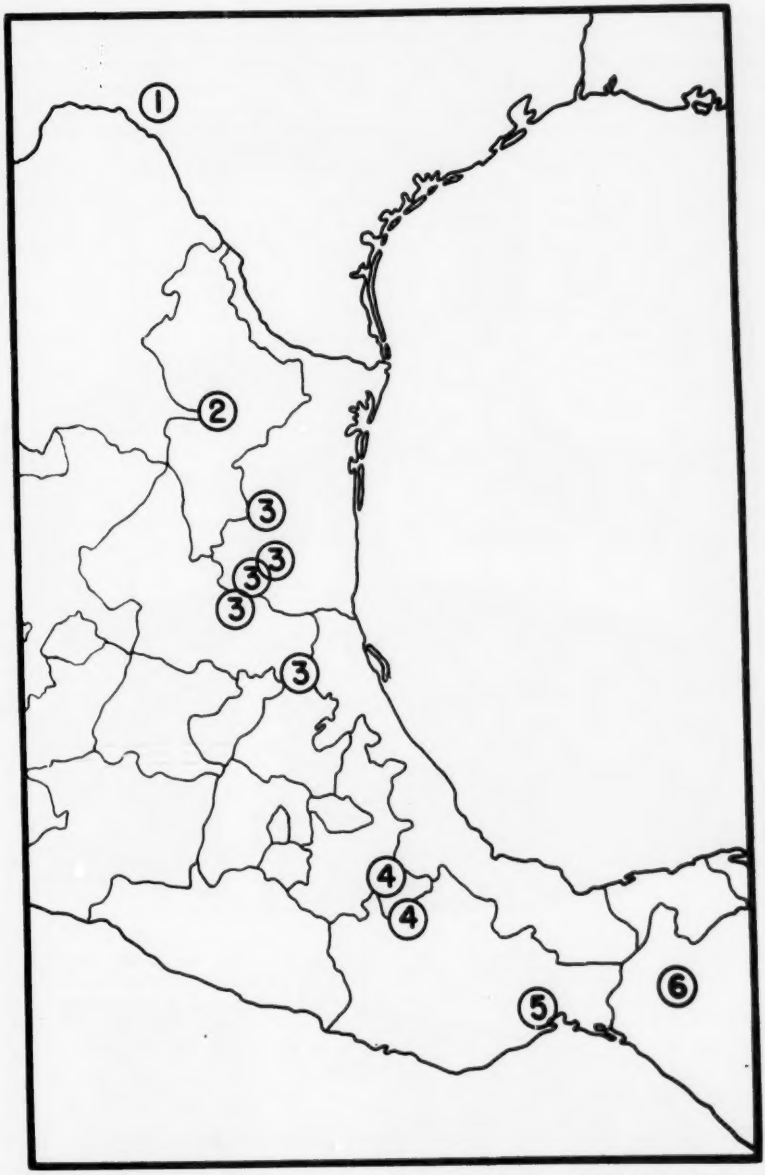

Fig. 2. Map showing collecting localities of specimens used. 1. Texas, 37 mi. North of Del Rio. 2. Nuevo Leon, "Horsetail Falls." 3. Several localities in southwestern Tamaulipas and eastern San Louis Potosi. 4. Localities in southern Puebla and northern Oaxaca. 5. Localities in the vicinity of Tehuantepec, Oaxaca. 6. Localities in the vicinity of Tuxtla Gutierrez, Chiapas.

white below. Ventral and subcaudal counts high, 174 and 73 respectively.

Description of the holotype.—Head rather depressed, top surface of head flat, head distinct from neck, snout rather broad and bluntly rounded. Rostral wider than high, about half of it visible from above; internasals much smaller than prefrontals, tip of the latter contacting second upper labial on left side of head, these two separated by posterior nasal on the right side. One preocular, about the size and shape of the posterior nasal. Two postoculars, the upper slightly larger. On the left side two elongate temporals bordering parietal shield, the posterior longer. On the right side three temporal scales bordering parietal, the anterior and posterior elongate, the middle one almost square. Upper labials seven, 3–2–1–4–6–5–7 in order of increasing size; third and fourth bordering the eye. Mental separated from anterior chin-shields by tips of first lower labials, which just touch. First four lower labials contacting anterior chin-shield on each side; only the fourth contacts the posterior chin-shield. Dorsal scales smooth, in 15 rows. Anal divided. Ventrals 174, subcaudals 73. Body slender, 172 mm. snout-vent, tail 49 mm.

Body color tannish-gray above (in life), fading into immaculate white below. Head black to tips of parietals and temporals, with a posteriorly directed trident extending from between parietals onto first vertebral scale and part of second, plus medial halves of first paravertebral scales. Tip of snout same light color as body, including rostral and greater part of internasals, anterior nasals, and first upper labial. This light color also found on parts of the posterior nasal and second upper labial, and on lower anterior corner of fourth upper labial. Most of fifth upper labial and adjoining edges of sixth and of anterior temporal are involved in a white marking about the size of eye. Lower labials and mental black, except that mental and first three labials also have white posteriorly and medially. A white nuchal collar present, extending back about two scale-lengths behind parietals, in

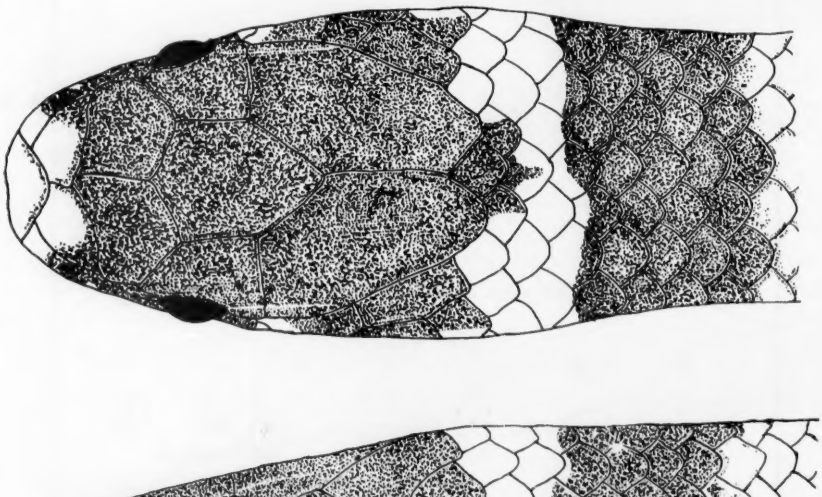

Fig. 3. Head of *Tantilla diabola*, TNHC 24647.

Fig. 4. *Tantilla diabola*, photographed in life.

turn bordered posteriorly by a black band about four-and-a-half scale-lengths long, the black pigment extending down to first scale row on each side.

Relationships.—Tantilla diabola seems to belong to the *T. coronata* group of Smith (1942). It is apparently most closely related to *T. rubra*, which is known from the Mexican states of Chiapas, Oaxaca, Puebla, San Luis Potosí, Tamaulipas, and Nuevo Leon. We assumed at first that the only differences between our specimen and *rubra* were too minor to be of specific significance. However, in order to establish the extent of these differences we examined 50 specimens of *rubra* from all parts of its known range. We found that certain characteristics of *rubra* are consistent throughout its range and differ from those of the specimen of *diabola*.

In *diabola*, the parietals and posterior temporals are entirely black, including the posterior tips, whereas in *rubra* the posterior tips are involved in the nuchal collar and are usually white or reddish (in three specimens from Chiapas, the entire posterior temporal is black, and in one the parietals are black to the tip). In *diabola*, the first vertebral scale is entirely black, whereas in *rubra* this scale is involved in the light nuchal collar and is entirely light or at most may have the anterior tip black. A partially divided collar as in *diabola* is unknown in *rubra*. The body color

is tannish-gray above and white below in *diabola*, and it is reddish above and below in *rubra*. In *rubra*, the lower postocular is usually white, or white with a black anterior margin, and the fourth upper labial generally has a white posterior border; but in *diabola* both postoculars are entirely black and the fourth upper labial is black to the posterior margin. Ventrals and subcaudals are more numerous in *diabola* than in *rubra*. In *rubra* ventrals number 147 to 167, subcaudals 56–70. Numbers of ventrals and subcaudals of *rubra* are graphically compared with those of *diabola* in Figure 1. Both counts are higher in *diabola* than in any *rubra*. Clinal variation seems evident in the *rubra* populations for both characters. The ventral count of *diabola* might be interpreted as part of this cline, but no such interpretation is possible with regard to the subcaudals. The localities where *rubra* and *diabola* have been found are shown in Figure 2, which indicates the samples grouped in Figure 1.

Four other species of this genus are known from Texas. Three of these belong to the *nigriceps* group and the other to the *gracilis* group of Smith (1942). The latter group is represented by *T. gracilis*, which has a conical head with no black pigment, no nuchal collar, and six upper labials. The Texas representatives of the *nigriceps* group include *nigriceps*, which has no nuchal collar; *atriceps*, which may have a faint nuchal collar but no posterior black border; and *cucullata*, which has a black head and neck, but no light collar.

Acknowledgments.—We are grateful to the following people and institutions for the use of specimens: W. F. Blair, University of Texas Natural History Collection; C. M. Bogert, American Museum of Natural History (AMNH); M. Alvarez del Toro, Museo Zoologico de Tuxtla Gutierrez (MZTG); R. F. Inger, Chicago Natural History Museum (CNHM); H. M. Smith, University of Illinois Museum of Natural History (UIMNH); and C. F. Walker, University of Michigan Museum of Zoology (UMMZ). W. F. Blair also read the manuscript. We also wish to thank Mr. and Mrs. G. E. Drewry for donation of the novel specimen.

Specimens examined (*T. rubra*).—*Nuevo Leon:* CNHM 30825. *Tamaulipas–San Luis Potosi:* AMNH 66161, 79960; UMMZ 107145–46, 111042, 111044, 111046–52. *Southern Puebla–Northern Oaxaca:* AMNH 65141; CNHM 105339, 105341, 105343; UIMNH 48562–63. *Tehuantepec* (*Oaxaca*) *area:* AMNH 62644–45, 62922–25, 65884, 66796, 66959, 68025, 68883; CNHM 82728, 105340, 105342, 105344; UIMNH 3773–74, 36815, 37145–46, 48561; UMMZ 82728. *Chiapas:* UIMNH 37991, 38041; UMMZ 102239; MZTG 76, 259, 411, 425, 434, 435.

In addition, ventral and subcaudal counts were included on the basis of published information for CNHM 40813 from Nuevo Leon (Smith, 1944).

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Department of Biology, University of Florida, Gainesville, and Department of Zoology, University of Texas, Austin.

Cnemidophorus inornatus, the Valid Name for the Little Striped Whiptail Lizard, with the Description of an Annectant Subspecies

Ralph W. Axtell

In 1858, Spencer F. Baird described two lizards, *Cnemidophorus inornatus* and *Cnemidophorus octolineatus*, on the same page of the Proceedings of the Academy of Natural Science of Philadelphia. Both new species were collected by the same man (Lt. D. N. Couch) at the same locality—the village of Pesqueria Grande (subsequently changed to Villa de Garcia), in the Mexican state of Nuevo León. The two cotypes of *C. inornatus* (United States National Museum 3032), although in very poor condition, are rather dark (deep brown from many years in preservative), completely unstriped lizards hav-

ing 80 and 85 granular dorsal scale rows (according to Dr. Doris M. Cochran), while the type of *C. octolineatus* (USNM 3009) has eight light stripes on a dark background and only 66 dorsal granules.

A brief history reviewing the nomenclatorial association of *C. inornatus* and *C. octolineatus* with each other, and with the lizard commonly called the little striped whiptail may be enlightening. The descriptions of both species (Baird, 1858:255) are repeated below:

> "*Cnemidophorus inornatus,* Baird—Scales on the gular fold smaller than those on the breast anteriorly, and scarcely larger than those on the middle of the chin. Scales of back tubercular and elevated. Hind feet about two-fifths the head and body. General color light greenish olive, paler beneath. No lines on the body.
>
> Hab.—New Leon. Lt. Couch. Type No. 3032.
>
> *Cnemidophorus octolineatus,* Baird—Gular fold as in the last. Hind foot not two-fifths the head and body. Scales of back depressed. General color light greenish olive, paler beneath. Back with eight equidistant and approximated light lines.
>
> Hab.—New Leon. Lt. Couch. Type No. 3009."

Subsequently both names were retained by various authors until about 1906, after which they slipped, for unknown reasons, into the synonymy of other *Cnemidophorus.* The two names were consistently synonymized, always under different headings. Burt (1931:9) placed *C. inornatus* under *Cnemidophorus sexlineatus gularis,* and *C. octolineatus* under *Cnemidophorus sexlineatus perplexus.* Schmidt and Smith (1944) lifted *octolineatus* from synonymy to apply to a lizard occurring in the mountainous regions of central Coahuila, Mexico. Burger (1950) has more recently referred Schmidt and Smith's *octolineatus* to *Cnemidophorus sacki semifasciatus.* Smith (1946) contributed to the already growing confusion by using *octolineatus* as the subspecific name of yet another form of *C. sacki,* which recently has been identified and described as a distinct subspecies (*C. s. exsanguis*) by Lowe (1956). The name *C. inornatus* was brought out of synonymy by Burger (1950) to become a substitute name for *C. perplexus,* after it was discovered that earlier confusion in type designation had irrevocably placed the name *C. perplexus* with a lizard of a different species, and not with the little striped whiptail. See both Burger (1950) and Maslin et al. (1958) for comments on this problem. Burger (op. cit.) relegated *C. octolineatus* to the synonymy of *C. inornatus,* thus being the first to indicate that these two lizards might be identical. The implication of the possible synonymy of these two names has stirred considerable skepticism among the interested saurologists. Do two different, closely related species live at the original collecting site, or only one dimorphic species?

At the onset (1958) of preparation for my work on Texas lizards many systematic problems involving forms occurring within Texas have presented themselves. As the taxonomic status of *C. inornatus* was one of the most controversial and insecure, I decided to visit the type locality of that species to try to answer the question of dimorphism posed above, and in doing so resolve our future use of the names *C. inornatus* and *C. octolineatus.* On June 9 and 10, 1960, Michael Sabath and I collected 14 (6 ♂, 8 ♀), *Cnemidophorus inornatus* from a group of wind formed, sandy mounds (about eight feet high) across the Rio Pesquería from Villa de Garcia. Of these 14 specimens, six were completely unicolor brownish olive above, and eight were distinctly striped with eight light lines on a brownish gray to olive background. We found six unicolor and five striped members of both sexes living within a small dune area estimated to be 50 yards wide by 100 yards long. Approximately 100 yards southeast of the dunes, among several small mounds (not over one foot high), we took three more individuals, but all of these were striped. This suggests that strong selection pressure may be active outside the restricted dune area, but more evidence for this is needed. From cursory observation the ratio of striped to unicolor individuals in the main dunes population appeared to be one to one, and the number of specimens collected by Sabath and myself (both morphotypes were in equal demand) tends to substantiate this observation. Unicolored individuals were the same color as, and therefore blended with the substratum. To my eye, unicolored lizards were more difficult to trail than were the striped members. This might explain their relatively high survival rate in the main dunes, but not in peripheral non-dune areas. The venters of both color forms were similar.

Although little time was spent noting behavioral phenomena at the collection sites,

TABLE 1. COMPARISON OF THREE CHARACTERS IN BOTH COLOR FORMS OF *Cnemidophorus i. inornatus* WITH *C. i. heptagrammus* ssp. nov. MEANS IN PARENTHESES

Character	Unicolor form Villa de Garcia, Coahuila	Striped form Villa de Garcia and other loc.	*heptagrammus* Trans-Pecos Texas
Scales around midbody			
♂	N = 1 74	N = 8 64–78 (71.1)	N = 37 55–71 (62.5)
♀	5 69–80 (75.4)	9 66–76 (69.5)	22 55–68 (64.3)
Sum of femoral pores			
♂	1 36	8 32–37 (33.9)	37 25–35 (30.9)
♀	5 30–35 (32.8)	9 29–37 (34.3)	22 28–36 (30.8)
Lamellae of fourth toe			
♂	1 31	8 27–34 (30.8)	37 25–32 (27.5)
♀	5 30–32 (31.0)	9 27–33 (30.9)	22 24–32 (27.3)

on one occasion a striped male was observed pursuing a unicolor female. Both individuals were collected to check their sex.

Although the sample is small there seems to be some correlation between a non-striped pattern and more numerous granular scale rows (Table 1). The significance of this is unexplainable at the present time and with the present material. The types of *C. inornatus* and *C. octolineatus* (supra) have such a large hiatus between granular midbody counts that some workers have regarded this character and the absence of stripes as being important enough to warrant distinction of the two forms as full species. On the grounds of what I have observed in the field and noted in the laboratory (twenty different observations per specimen), I cannot agree that they are different species. Pattern dimorphism in reptiles has caused considerable taxonomic confusion before (see Mecham, 1957, Klauber, 1936, 1939, 1944 and Smith, 1943), but now that we are aware that such genetic phenomena occur in natural populations, our ideas should be benefited by them.

If we are to abide strictly by the Rules of Zoological Nomenclature, *Cnemidophorus inornatus* is the correct name (based on line priority) for the little striped whiptail. As *C. inornatus* has never been properly characterized, a redescription follows:

Cnemidophorus inornatus Baird

Distribution.—Principally an elevated plains or alluvial flatlands whiptail occurring in Mexico from central San Luis Potosí northward through Coahuila, extreme southeastern Nuevo León, eastern Zacatecas and Durango, Chihuahua, and northeastern Sonora. In the United States it occurs from the Devil's River of Texas, westward through southern New Mexico and extreme southeastern Arizona. Vertical distribution from about 1,000 to 6,500 feet, but infrequent above 5,500 feet.

Diagnosis.—A member of the *sexlineatus* group of the genus *Cnemidophorus* with slightly enlarged postantibrachials (two to four times size of adjacent lateral scales); usually no more than two or three transverse series of slightly enlarged mesoptychials (five to ten times size of granules in gular fold); eight rows of enlarged plate-like ventral scutes; supraorbital semicircle scales seldom extending anteriorly beyond the posterior edge of frontal; dorsal granules at midbody generally fewer than any other member of group, 55 to 85, averaging 63.92; sum of femoral pores 25 to 42, averaging 30.72; preanal scales 2 to 8, averaging 3.47; dorsal markings, a series of light stripes (variable in number) on an unmarked, dark background (dark color usually becomes lighter with age); ventral surface without dark markings, but usually bluish white; chin, belly of adult males and tail of both sexes usually more vivid blue or blue-violet.

Geographic Variation.—The number of dorsal stripes in *C. inornatus* is known to vary geographically. Burger (1950:3) observed

variation in dorsal striping, but presumably regarded it as broadly clinal over the entire range of the species (decrease in striping from southeast to northwest), and therefore not usable for defining discreet subpopulations. Fugler and Webb (1956) presented additional evidence of variation, but confined their discussion to the lizards from a single collection site. With regard to dorsal striping, the populations of *C. inornatus* that I have observed segregate into four fairly homogeneous geographic populations: 1) eight-striped populations on the high plateau of Mexico, in the states of San Luis Potosí and Zacatecas, 2) eight-striped populations (a split vertebral stripe) in arid west central Nuevo León and southeastern Coahuila, 3) seven-striped populations (a single vertebral stripe) in northern Coahuila (a broad hiatus or relictual populations may occur in central Coahuila), eastern Chihuahua, Trans-Pecos Texas and up the Pecos River Valley to central New Mexico, and 4) six-striped populations (no vertebral stripe) in western New Mexico, southeastern Arizona, northeastern Sonora, and western Chihuahua. Material for the above observations has come from both cursory and concentrated field work on this problem since 1955. As Mr. Kenneth Williams of the University of Illinois has been working on western members of the species for several years, I have conceded treatment of these forms to him, and will concentrate solely on eastern representatives of *C. inornatus* for the remainder of this paper.

There is a consistent difference in the dorsal striping of *C. inornatus* populations from two definable ecological and physiographic regions in northeastern Mexico. As additional characteristics add weight to the striping difference, I believe these two populations should receive subspecific recognition.

Cnemidophorus inornatus inornatus Baird
Eight Striped Whiptail
Fig. 1, A & B

Cnemidophorus inornatus Baird, 1858: 255; Boulenger, 1885: 360, Cope, 1900: 590; Gadow, 1906: 373; Burger, 1950: 2 (part); Smith and Taylor, 1950: 184 (part).
Cnemidophorus octolineatus Baird, 1858: 255; Cope, 1900: 589; Gadow, 1906: 373.
Cnemidophorus sexlineatus gularis, Burt, 1931: 98.
Cnemidophorus sexlineatus perplexus, Burt, 1931: 122.

Lectotype.—Adult female, USNM 3032 A (by present designation)[1] collected by Lt. D. N. Couch in 1853.

Type Locality.—25° 49′ N–100° 35′ W, Pesquería Grande (= Villa de Garcia), Nuevo León, Mexico. Elevation, 2,500 ± feet.

Diagnosis.—A subspecies of *Cnemidophorus inornatus* with a dorsal pattern of eight light stripes on a gray to brownish green ground color, or a brownish green dorsum without markings; dorsal granular scales at midbody usually 69 or more in both sexes (73% of sample); lamellae on longest toe of hindleg usually 30 or more in both sexes of (79% of sample); and paravertebral light stripes (first lateral from split vertebral stripes) reaching anteriorly to enlarged occipital scales, absent or not clearly defined on parietals or supraoculars.

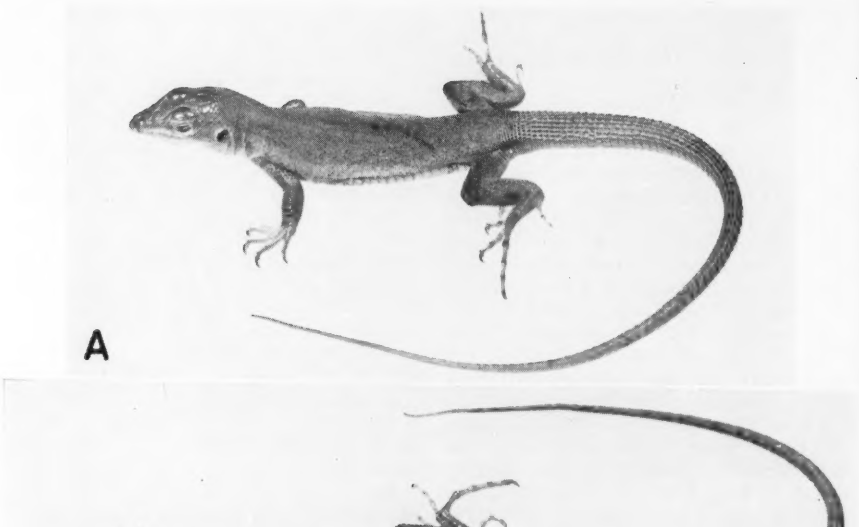
Description.—This description is based on 24 specimens (9 ♂, 15 ♀). All measurements are in millimeters.

Maximum snout-vent length of male 60.7, of female 63.2; average length of adults (those over 50.0) 57.6; total length of largest specimen examined 203.6 (♂); forelimbs averaging 31 per cent of snout-vent in males, 30 per cent in females; hindlimbs averaging 66 per cent of snout-vent in males, 63 per cent in females; length from axilla to groin 48 per cent of snout-vent in males, 51 per cent in females.

Number of dorsal granules at midbody 65 to 80 (71.6 ± 0.96); sum of femoral pores 29 to 37 (33.9 ± 0.45); transverse lamellae on longest phalange of hindfoot 27 to 34 (30.9 ± 0.41); usually three or more supraorbital semicircle scales contacting lateral edge of frontoparietal; number of enlarged preanals variable, from 3 to 7 (4.14); ventrals from gular fold through preanals 35 to 41 (38.0). There appears to be little variation within the relatively small geographic range of this form.

Two strikingly different color phases exist (Fig. 1, A & B), one phase with eight light stripes, and another without stripes. In both phases the ground color is brownish gray, usually with a greenish iridescent tint. The dorsal head coloration is similar to that of the body. In the striped phase, the paravertebral light lines do not continue anteriorly across the occipitals onto the parietals or supraoculars. Ventrally the head, body and tail, and the sides of the head are bluish in most individuals. Distally the tail

[1] Burger (1950) designated USNM 3022a as the lectotype for *C. inornatus*. As this number is incorrect, and as no identifying marks were placed on the selected specimen or tag, I have marked and redesignated a lectotype.



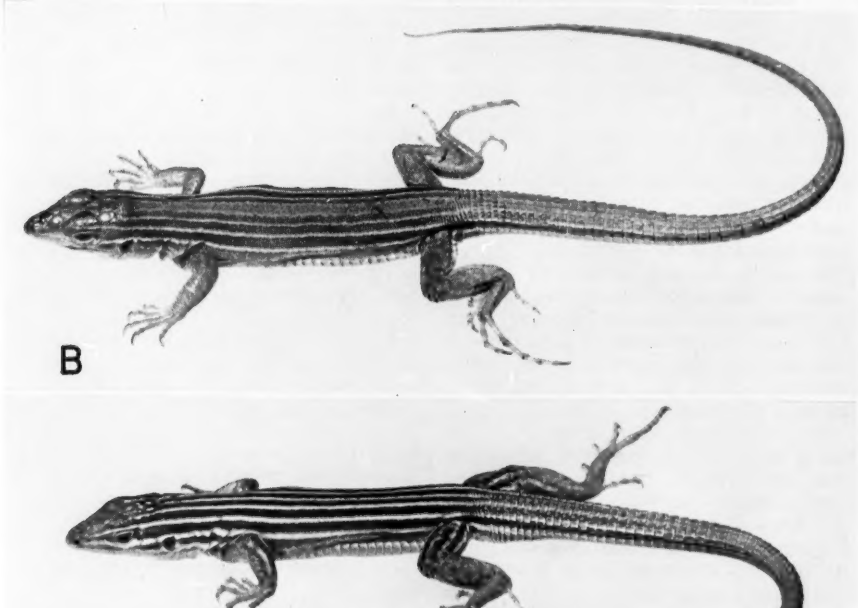


Fig. 1. (A and B) *Cnemidophorus inornatus inornatus*, both from Villa de Garcia, Nuevo León, Mexico. (A) RWA 2784 ♀, total length 172.1 mm.; (B) RWA 2793 ♀, total length 194.3 mm. (C) *C. i. heptagrammus* ssp. nov., 4 mi. W. Terlingua, Brewster Co., Texas (RWA skel. ♂).

is usually purplish blue. Sexual dichromatism is evident with ventral coloration in adult males being vivid blue-gray and in females gray with only a slight tint of blue. Juvenile coloration is unknown. Two to eight scales may be present between the vertebral stripes. The vertebral dark field is lighter than the lateral dark fields, and in several specimens there is a faint indication of two additional (9th and 10th) light lines in this area.

The eight striped pattern is consistent (100% of 17 specimens). Whether this consistency will be maintained throughout the entire range of the subspecies has yet to be determined.

Comparisons.—*Cnemidophorus inornatus inornatus* differs from the more northerly distributed seven-lined form in possessing 1) eight dorsal light lines, or none at all; 2) a lighter brownish green or brownish gray dorsal ground color (not dark gray to black); 3) a ventral coloration of blue-gray (♂) or gray (♀), as compared to much brighter sky blue (♂) or bluish white (♀) in the seven-lined form; 4) dorsal granules usually 69 or more; 5) usually 30 or more lamellae under longest toe of hindfoot; 6) usually three or more small posterior semicircular scales contacting the frontoparietals; and 7) paravertebral dorsal light stripes fading abruptly on the occipital region of the head, and not continuing as a well defined line onto parietals, supraorbital semicircles or supraoculars.

As only the seven and eight-lined populations are to be discussed formally here, I will not attempt to compare either of these populations with the more westerly distributed populations. At least some of the differences between the several forms of the species are incorporated in the diagnoses of the two populations considered here.

Intergradation.—The sample material used in the above description shows no definite tendency toward integradation with any other subspecies. Fugler and Webb (1956) reported a population of *C. inornatus* near Parras, Coahuila, from which they collected individuals having seven striped (eight) and eight striped (six) patterns. The Parras area might be a location favorable for the meeting and admixture of populations from the highlands of southern Coahuila and the Coahuilan lowlands to the northeast (see fig. 2). The populations occurring within that area might just as easily be recognized as a northern segment of the highland Coahuila-Zacatecas populations which are showing clinal loss of an eight striped condition toward the west, for it is known that specimens from northeastern Zacatecas are mostly eight-striped while those from lower elevations in northeastern Durango are seven-striped. Of course there may be three-way contact of populations in the Parras area. Much additional material will have to be examined before this problem can be resolved.

Habits and Habitat.—This is a shy whiptail, more difficult to approach and collect than its northern relative. The period of greatest diurnal activity during June appears to be the morning hours (from 8:00 to 11:30 AM), with very little to no activity in the afternoon. The few observations indicate that females make up the majority of active individuals after about 11:00 AM. Individuals seem to prefer rather flat, grassy alluvial deposit areas or gentle slopes where there are intermittent open areas. They forage for food along the edges of grassy patches where they can remain close to protective cover and shade. The population at Villa de Garcia occurs in an area of small sandy hillocks covered by thorny vegetation, with areas of grass and weeds on the flats between. Farther westward, specimens were found on the more xeric, sparsely vegetated Plan de Guadalupe, a flat bolson, adobe-fill area broken by many crescentric Upper Cretaceous sandstone cuestas.

Distribution.—(Fig. 2). This lizard is restricted so far as is known to the intermontane valleys and bolson basins drained by the Rio Pesquería, Rio Salinas, Rio Tortuga, Arroyo San Diego and Arroyo Huisache. It has been found as far north as Gloria in the upper Rio Sabinas drainage, but apparently does not occur north of Monclova, Coahuila. Locality records follow: MEXICO.—*Coahuila:* 26° 42′ N–101° 23′ W, at Gloria (R. W. Axtell collection 1376); 26° 40′ N–101° 23′ W, WSW. Gloria (RWA 1371–2); 26° 38′ N–101° 23′ W, S. Gloria (RWA 2773); 26° 13′ N–101° 18′ W, N. Guadalupe (RWA 2778); 26° 03′ N–101° 21′ W, S. Guadalupe (RWA 2770–1); 26° 05′ N–101° 21′ W, S. Guadalupe (RWA 2772); 26° 08′ N–101° 03′ W, E. Reata (RWA 2794). *Nuevo León:* 25° 48′ N–100° 35′ W, S. Villa de Garcia (RWA 2779–93).

Restriction of the name *C. i. inornatus* to striped whiptail populations occurring in southeastern Coahuila and west-central Nuevo León, leaves the *C. inornatus* populations of northern Coahuila, northeastern Chihuahua, western Texas and southeastern New Mexico nameless. I therefore propose:

Cnemidophorus inornatus heptagrammus *ssp. n.*
Seven Striped Whiptail
Fig. 1, C

Cnemidophorus perplexus Baird and Girard, 1852: 128 (part); Strecker, 1909: 14; Van Denburgh, 1922: 495 (part); Schmidt and Smith, 1944: 86; Smith, 1946: 412 (part); Jameson and Flury, 1949: 64; Brown, 1950:

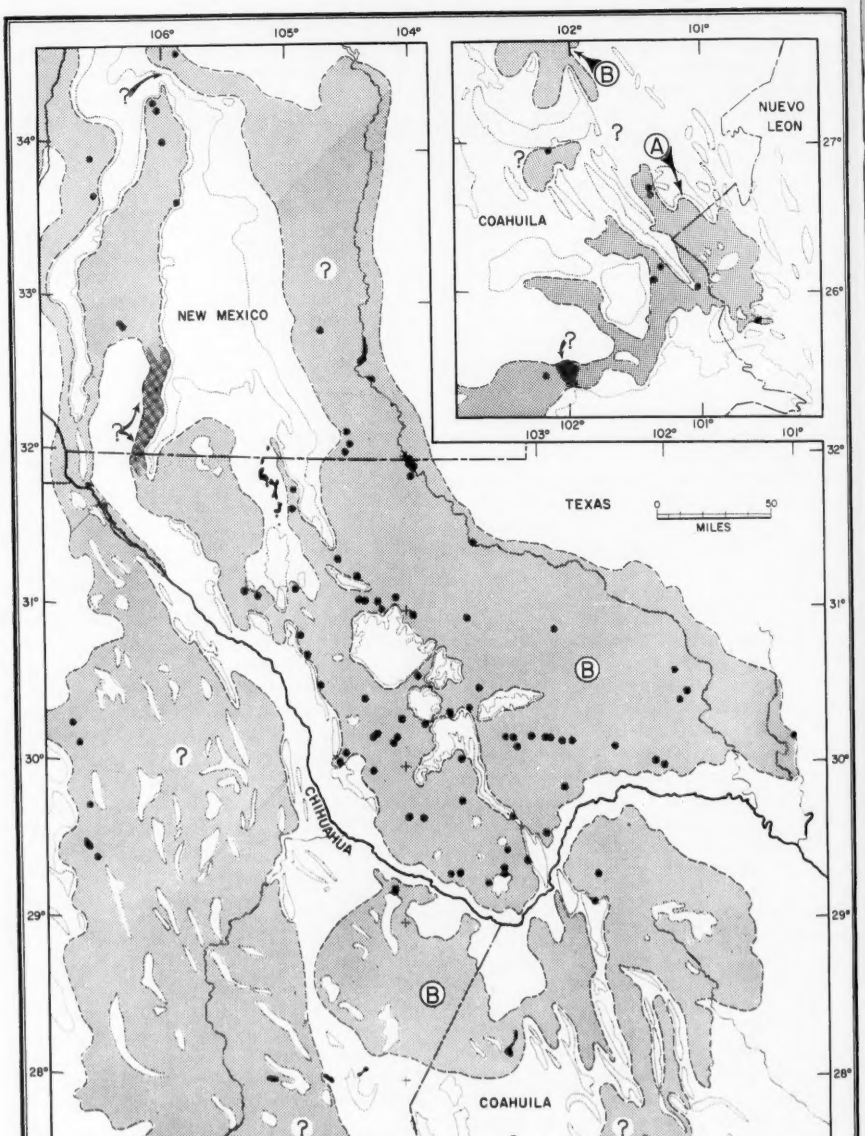


Fig. 2. Map of a part of the hypothetical range of *Cnemidophorus inornatus*, with black dots representing locality and reliable literature records. The distributions of *C. i. inornatus* (A), and *C. i. heptagrammus* (B), and extralimital forms are shown. White areas surrounded by stipple are not considered to be habitable by *C. inornatus*. Supposed areas of intergradation are marked by overlapping stipple, and areas of questionable range are marked by question marks (?).

127; Milstead, Mecham and McClintock, 1950: 553; Schmidt, 1953: 146 (part); Milstead, 1957: 228; Minton, 1958 (1959): 45.

Cnemidophorus sexlineatus, Gadow, 1906: 302 (part).

Cnemidophorus sexlineatus perplexus, Burt, 1931: 122 (part).

Cnemidophorus inornatus, Burger, 1950: 2 (part); Smith and Taylor, 1950: 184 (part); Milstead, 1953: 411; Schmidt, 1953: 146 (part); Stebbins, 1954: 288 (part); Axtell, 1959: 100.

Holotype.—Adult male, RWA 1758, collected by Ralph W. Axtell, May 16, 1959.

Type Locality.—30° 11′ 30″ N–103° 09′ W, 5 mi. ESE. Marathon, Brewster County, Texas. Elevation 4,150 feet.

Diagnosis.—A race of *Cnemidophorus inornatus* with a dorsal pattern of seven light stripes on a dark gray to black ground color; dorsal granular scales at midbody usually less than 69 (89%) in both sexes; lamellae on longest toe of hindfoot usually less than 30 (84%) in both sexes; and paravertebral light stripes reaching anteriorly to parietals, supraorbital semicircles or supraoculars.

Description of Holotype.—An adult male, snout-vent length 58.4; tail length 130.0 (complete); foreleg 18.0 (ratio foreleg to snout-vent 0.308); hindleg 38.8 (ratio hindleg to snout-vent 0.664); head length 13.6, width 9.0; snout to posterior edge of interparietal 13.0; axilla-groin length 29.0 (ratio axilla-groin to snout-vent 0.497); circumferential dorsal granular scales at midbody 59; lamellar count for manus 9–12–15–15–11 (R), 10–13–14–14–11 (L), for pes 17–27–20–15–10 (R), 15–28–20–14–10 (L); 161 dorsal scales from interparietal to first enlarged scales of tail; 15–15 femoral pores; 37 ventrals from enlarged preanals to gular granules; enlarged preanals 4; circumferential number of caudals 20 mm. posterior from vent, 16. Diagnostic characteristics of head scutellation few. Most notable are: posterior three supraoculars cut off completely on right side and partially on left side by row of ciliary granules projecting medially; row of ciliary granules includes small supernumery scale split off posterior edge of anterior supraocular; 2–2 posterior semicircular scales contacting frontoparietals posterolaterally; small supernumery scale between anterior parts of left parietal, interparietal and median posterior edge of frontoparietal; 13 enlarged occipital scales; 5–5 supralabials; 6–6 enlarged infralabials bordering supralabials below, and projecting for some distance past last supralabial; 1–1 preoculars; 3–3 suboculars; 3–3 postoculars; 9–8 superciliaries; 6–6 chinshields; sublabials reaching anteriorly to third infralabials. Color pattern (in alcohol), seven cream-white stripes extending from enlarged head scales to base of tail or hindleg; vertebral stripe stops at enlarged occipitals; paravertebral stripes continue anteriorly to second and third supraoculars on both sides; dorsolateral stripes continue anteriorly along superciliaries to loreals; lateral stripes begin anteriorly at lower edge of eye, continue to groin, and extend along anterior edge of femora; lateral stripes begin anew behind femora and continue until they fade out on proximal fifth of tail; short light stripes extend from posterior edge of tympanic opening to merge with light ventral coloration above insertion of forelegs; dark gray ground color between light stripes becomes lighter below lateral stripes; light, lineate markings on dark background on dorsal parts of both fore and hindlimbs; tail grayish proximally changing to bluish gray distally; keel tips of proximal caudal scales blackish; bluish white ventral coloration extending dorsally to midpart of loreal and subocular region on head, to enlarged scales on anterior faces of both limbs, to several granules above enlarged ventral scales on body, and to lateral scales of tail; granular scales under foreleg, granules on postfemoral region, enlarged scales of tibia, preanal region, and median ventral part of tail cream-white, not tinted with blue.

Variation.—Based on 63 specimens (39 ♂, 24 ♀) from Trans-Pecos Texas and extreme northwestern Coahuila, Mexico. All measurements are in millimeters.

Maximum snout-vent length of male 65.2, of female 67.2, average of adults (individuals over 50.0) 55.9; total length of largest specimen examined 191.8 (♂); forelimbs averaging 31 per cent of snout-vent in males, 30 per cent in females; hindlimbs averaging 66 per cent in males, 64 per cent in females; length from axilla to groin 49 per cent in males, 53 per cent in females.

Number of dorsal granules at midbody 55 to 71 (mean ± standard error 64.1 ± 0.16); sum of femoral pores 25 to 36 (30.9 ± 0.29); number of transverse lamellae on longest phalange of hindfoot 24 to 32 (27.4 ± 0.24); two or less supraorbital semicircle scales contacting lateral edge of frontoparietal, at least on one side (75%); number of enlarged preanals from 2 to 6, averaging 3.6; ventrals from gular fold through preanals 34 to 42 averaging 37.2.

A pattern of seven white, cream, or yellowish light stripes on a ground color of varying shades of gray or black exists throughout the range of this subspecies. In examining 515 specimens I have found only 16 exceptions to the seven-striped pattern. Exceptions usually involve partial or complete absence, or splitting of the vertebral stripe. Dorsal head coloration is usually greenish olive to brown, and therefore lighter than the ground color of the body. The paravertebral light stripes extend anteriorly to either the parietals, supraorbital semicircles, or supraocular scales, giving the enlarged posterior head scales a vivid pattern. The sides and ventral surface of the head, and the ventral surface of the neck, body, limbs, and tail (with exception of lighter areas around the anal region), are sky blue in adult males and bluish to light bluish white in adult females. Distally the tail is sky blue to purplish blue in adults of both sexes and in juveniles. Ontogenetic change, although present, is not marked. Juvenile ground coloration is usually black, changing to lighter grayish black with adulthood. The light stripes are usually brighter in the young and may be yellowish in some individuals.

Comparisons.—Included under *C. i. inornatus.*

Intergradation.—The dearth of material from east-central Coahuila precludes any analysis of intergradation of this form with *C. i. inornatus.* A geographically intermediate population situated between *C. i. inornatus* and *C. i. heptagrammus* ranges has been found in the old lake basins of the Cuatro Cienegas area, Coahuila (see inset, Fig. 2). Although I have examined only one specimen (which has six light stripes instead of seven) from this area, its affinity was clearly with *heptagrammus* or other western forms, and not with *inornatus.*

Habitat.—This diurnal lizard occurs predominately on alluvial flats in sub-xeric to xeric vegetative associations throughout its range. It may be found on sandy, silty, or gravel flats and washes, and may occasionally wander onto adjacent sloping areas. It rarely frequents rough, excessively rocky areas. Population density seems to be related to the amount of vegetative cover in an area, with few individuals in extremely barren areas, a high density in open areas intermingled with patches of shrubs and grass, and again in low density in areas with complete grass cover.

Distribution.—(Fig. 2). *C. i. heptagrammus* occurs from northwestern Coahuila and eastern Chihuahua, Mexico, northward through Trans-Pecos Texas, and up the valley of the Pecos River to east-central New Mexico. Vertical distribution from about 1,000 to 5,500 feet. Locality data for 515 specimens and additional reliable records follow: MEXICO.—*Coahuila*: 29° 20′ N–102° 35′ W, S. Agua Salada (RWA 2828); 29° 08′ N–102° 32′ W, SW. La Noria (RWA 2826–27, 2852–62). *Chihuahua:* 29° 12′ N–104° 06′ W, in Sierra Rica (RWA 2796–2825, 2839–53); 29° 10′ N–104° 04′ W, in Sierra Rica (RWA 2854–55). NEW MEXICO.—*Eddy Co.*: Artesia, 15 mi. W. (University of Michigan Museum of Zoology); Carlsbad Caverns Nat. Park Hdqrs., 2 mi. W. (UMMZ); White City, 7 mi. SW., 10 mi. SW. (UMMZ). *Torrance Co.*: Lucy, 1.4 mi. SW. (RWA 1560, 1571–75). TEXAS.—*Brewster Co.*: Alpine, 5 mi. W. (RWA 1803–8), 10 mi. E. (Minton 1959), 22 mi. S. (RWA 1856–58), 44 mi. S. (RWA 1729); Big Bend Nat. Park Hdqrs., 8 mi. N. (Minton 1959); Black Gap Wildlife Manag. Area (Texas Natural History Collection—121 spec.); E. Burro Mesa (Brown, 1950), Dagger Flat (Minton, 1959); Hovey (Brown, 1950); Government Spring (Brown, 1950); Green Gulch (Brown, 1950); Longfellow, 46 mi. S. (TNHC 11705); Marathon (Minton, 1959), 4.3 mi. E. (RWA 1747–56), 5 mi. ESE. (RWA 1758–9), 5.5 mi. SE. (RWA 1762), 12 mi. E. (RWA 1768), 18 mi. E. (RWA 1769), 25 mi. E. (RWA 1783); McKinney Spring (Texas Cooperative Wildlife Collection 1152); Oak Springs, Chisos Mts. (TCWC 12946); Persimmon Gap (Minton, 1959); Terlingua (Brown, 1950), 4 mi. W. (RWA). *Culberson Co.*: 31° 21′ N–104° 31′ W, NW. Borracho (RWA 2486); Kent, 3 mi. S., 4 mi. W., 8 mi. W. (Brown, 1950); Lobo, 3 mi. SW. (RWA 1677); 31° 49′ N–104° 49′ W, SSW. Pine Springs (TNHC 20204); Van Horn, 9 mi. N., 40 mi. N. (Brown, 1950). *El Paso Co.*: El Paso, 11 mi. SE. (Brown, 1950). *Hudspeth Co.*: Sierra Blanca, 7.2 mi. ESE. (RWA 1695–7), 14 mi. ESE. (RWA 1681–84). *Jeff Davis Co.*: 30° 48′ N–104° 44′ W, S. Lobo (RWA 2035–7); Fort Davis (Brown, 1950); Madera Canyon (TNHC 7035); 30° 59′ N–103° 55′ W, NW. Toyahvale (RWA 2864). *Loving Co.*: Carlsbad, 40 mi. S. (Brown, 1950). *Pecos Co.*: nr. Fort Stockton (Brown, 1950). *Presidio Co.*: 29° 40′ N–103° 52′ W, Bandera Mesa (RWA 2865); Marfa (Brown, 1950), 9 mi. E. (TCWC 2832–3), 9.5 mi. SW. (RWA 1866–67, 1911–14, 2004), 11 mi. ESE. (RWA 1660–61), 11 mi. SW. (RWA 1891), 14 mi. SW. (RWA 1898, 2011), 19.1 mi. NW. (RWA 1662), 26 mi. SW. (RWA 1904), 63 mi. S. (TNHC—7 spec.); 30° 01′ N–104° 30′ W, in Pinto Canyon (RWA 2684);

30° 05′ N–104° 27′ W, NE. Ruidosa (RWA 2054–6, 2571); Valentine, 9 mi. W. (TNHC 4130–32), 10 mi. WSW. (TNHC—230 spec.), 11 mi. W. (TNHC 2886–95), 12 mi. SE. (RWA 2019–23). *Reeves Co.*: Balmorhea, 15 mi. E. (Brown, 1950); nr. Toyahvale (Brown, 1950). *Terrell Co.*: Comstock, 54.8 mi. WNW. (TNHC 243); Dryden, 2 mi. E. (RWA 2698); Sanderson, 21 mi. E. (RWA 2690–1); Sheffield, 13 mi. S. (TNHC 7752–4), 15 mi. S. (TNHC 7839+), 18 mi. S. (TNHC 8331+), 21 mi. S. (TNHC 8196+). *Ward Co.*: Pecos River at Pecos (Brown, 1950).

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My wife Joan deserves especial mention for her curatorial efforts and her continuous assistance in the field and laboratory.

Summary

Both *Cnemidophorus inornatus*, an unstriped whiptail lizard, and *C. octolineatus*, a striped lizard were described from Pesquerí Grande, Nuevo León, Mexico, by S. F. Baird (1858). A collecting visit to that locality (now known as Villa de Garcia) corroborated the existence of both color forms at one locality, and led to the discovery that they are conspecific. *Cnemidophorus inornatus* has priority over *C. octolineatus* and becomes the valid name for the species. The *C. inornatus* populations from Villa de Garcia differ significantly from one of the annectant populations. The divergent population, which occupies northern Coahuila and Chihuahua, Mexico, western Texas, and east-central New Mexico is named *Cnemidophorus inornatus heptagrammus* ssp. n., in allusion to its consistently seven-lined pattern.

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DEPARTMENT OF ZOOLOGY, SOUTHERN ILLINOIS UNIVERSITY, ALTON, ILLINOIS

Comparative Accumulation of Radioactive Zinc in Young Rainbow, Cutthroat and Brook Trout[1, 2]

JOHN V. SLATER

THE lethal action of dissolved salts of heavy metals on fish has been investigated in earlier studies by Carpenter (1927) and Jones (1938). The metabolic role of some of these same metal ions, known in low concentrations to play important parts as enzyme activators and essential nutritional components in various animals, has been little investigated in fish to the present time, however.

Interest in zinc accumulation, particularly Zinc 65, has recently been initiated by the Japanese especially in the vicinity of Bikini Atoll where observations on the nature of radioactive contamination in fish after the atom bomb explosion and zinc localization in certain pelagic forms have recently been published by Amano, *et al.* (1955), Saiki, *et al.* (1955) and Yamada (1955). The radioactive isotope of zinc was discovered to be responsible for much of the biological activity found in this area. Since zinc, in extremely low concentration, is known to be important from a nutritional viewpoint and yet also known to limit survival (Affleck, 1952) it was thought to be of interest to determine the rate of accumulation of this ion and to investigate its subsequent localization. Since comparative studies on ion accumulation in fish are also much needed, the uptake in three different species was studied.

MATERIAL AND METHODS

Fingerling trout ranging in size from 38–52 mm and in age from 7–8 months were obtained from the fish hatchery at Kalispell, Montana, during the months of July and August in 1958. The species employed were rainbow trout, *Salmo gairdneri*, of the Winthrop Washington Strain, brook trout, *Salvelinus fontinalis*, from the hatchery at Omak, Washington, and cutthroat trout, *Salmo clarki*, grown at the Kalispell Hatchery.

The fish were incubated at 10–12.5°C in a water bath at the Biological Station of Montana State University and natural lighting occurred throughout the experiment. The animals were placed singly in 600 ml. Pyrex beakers containing 200 ml. of radioactive zinc solution made up in filtered Flathead Lake water. The top of each beaker was covered

[1] The aid of Mr. B. H. Cook, Head Manager, and Mr. Fred J. Howard, Assistant Hatchery Manager, of the Kalispell Fish Hatchery, United States Fish and Wildlife Service is gratefully acknowledged in supplying fingerling trout for this experimentation.

[2] This work was supported by grants from the United States Atomic Energy Commission and the National Science Foundation in Aid to a Radiation Biology Institute at the Montana State University Biological Station at Flathead Lake, Montana.

with aluminum foil to prevent splashing and also to protect the fish from external stimuli so as to avoid over-exciting them. Final concentration of the zinc was 0.1 μc/ml. and the added zinc ion concentration was equal to 0.37 μgm/ml. (0.37 ppm.).

The fish were washed free of external activity with running tap water at appropriate time intervals and dried to a constant weight at 80°C prior to all counts. Their weights varied from 0.12–0.58 gms. They were then placed in plastic tubes and counted in a Nuclear Chicago (Model DS-5) Deep Well Scintillation Detector with a Nuclear Chicago Scaler (Model 186) set at 1500 volts. All counts were taken over 10 minute time intervals and computed on the basis of counts per minute per milligram of dry fish. Four series of experiments were undertaken to evaluate the comparative uptake of zinc on a whole fish basis. At least two fish per time interval were used. One series involving three fish of each species was used to study zinc ion localization. Accumulation in the gill filaments, operculum, tail and ventral body wall areas was studied in the rainbow and cutthroat trout. Fish were permitted to remain in a solution of Zn^{65} for 48 hours for this purpose.

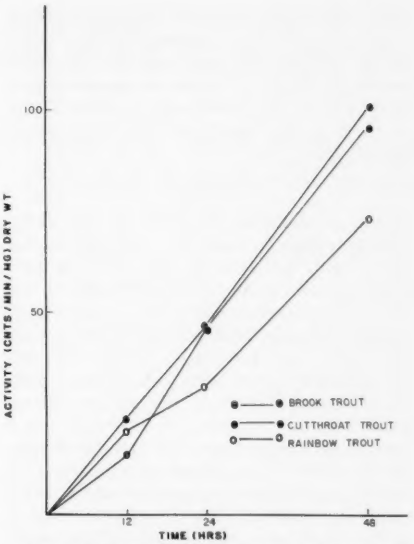

FIG. 1. Rate of accumulation of ZN^{65} with time in three species of American Trout. 0.1 microcuries/ml of Zn^{65}. Intact fish. Average values from four series of experiments.

RESULTS

The time intervals studied for the rates of zinc accumulation were 12, 24 and 48 hours. Longer exposure periods were not feasible since survival under the experimental conditions was limited to four days.

At 12 hours (Fig. 1) brook trout had accumulated the smallest amount of zinc with the cutthroats taking up the largest amount; but after two days, rainbows had accumulated a significantly lower amount of this metal than evident in either of the other two species.

Analysis of the rates of accumulation of zinc by the three species of fish revealed that the greatest rate occurred in the brook trout. This was equal to 37 $\times$ 10^{-3} counts/mg/min between 24 and 48 hours of exposure. The cutthroats accumulated only 92 percent of this value and the rainbows took up only 75 percent of the amount of zinc found in the brook trout. The uptake by the cutthroats was equal to 34 $\times$ 10^{-3} counts/mg/min and the uptake by the rainbows equaled 24 $\times$ 10^{-3} counts/mg/min.

It is seen in Fig. 2 that the uptake of radiozinc was highest in the gill filament regardless of the species but that the quantity of Zn^{65} found in the operculum of the rainbow was

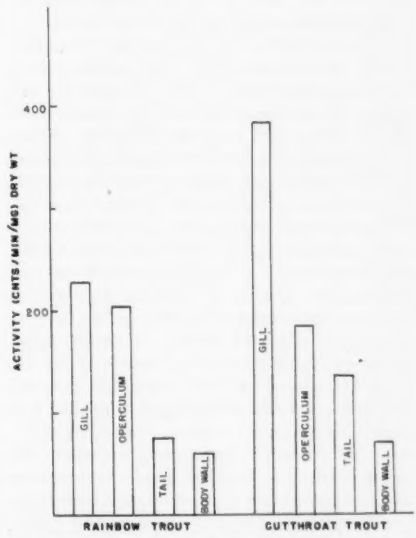

FIG. 2. Accumulation of radioactive zinc in various structures of rainbow and cutthroat trout. Time of exposure 48 hours. Concentration of Zn^{65} = 0.1 microcurie/ml.

almost the same as that found in the gill of that animal. In either species, the zinc found in the ventral body wall was less than that found elsewhere. The zinc accumulation in the gill of the cutthroat trout was almost twice as much as that found in the operculum in that species.

Discussion

The accumulation of radioactive zinc in fingerling trout was found to be greatest in the brook trout and least in the rainbows. Animals appeared to be quite healthy during the 48 hours of exposure, and the final appearance of the fish would lead one to believe that no gill mucus was formed as noted with the stickleback by Jones (1938) where heavy metals became adsorbed on the surface of the gills.

No food was given to the animals during the duration of the experiment in order to avoid possible ion adsorption effects. The accumulation of the radioisotope was higher in the gill tissue than in any of the other areas studied indicating either a greater degree of metabolic activity here than elsewhere or greater surface adsorption. Localization studies by Saiki, *et al.* (1955) in regard to Zn^{65} in fish showed that after the atomic explosion at Bikini the greatest amount of zinc was found to be present in the spleen with decreasing amounts (in order) found in the kidney, liver, pyloric caeca, heart, gill, intestine, gastric wall, ovary, testis, red muscle, skin, vertebrae and muscle. Also in general the highest amount was found in the viscera with less in bone, skin and muscle. Some of the isotope washed free of the organs very easily, a mere washing with water or Na-EDTA being quite effective. This would indicate that the isotope was perhaps merely adsorbed on the surface of the organs and was not tied up metabolically in any way. Work on the incorporation of Zinc 65 into the goldfish by Miura and Tsunoshima (1956) wherein temperature was varied during the experiment appeared to indicate that some metabolic pathways were involved, since the amount taken up increased with temperature and was greater than could be accounted for by diffusion. The ratio of uptake or distribution between bone and muscle was constant but black colored fish absorbed a large amount of zinc in their pigment layer suggesting a possible combination of zinc with melanin or associated intermediates.

Zinc is very widely distributed in both animals and plants being found in marine invertebrates, and generally in vertebrate animals. It is found in the red blood cells of vertebrates and appears to be correlated with the amount of carbonic anhydrase present. Zinc is also found in the blood plasma and the retina, choroid and iris of the eye, being especially prominent in the eye of the fish. Also in view of the fact that the insulin molecule is believed to contain zinc the pancreas is especially rich in this element.

With the fish, *Tilapia mossambica*, Boroughs, Townsby and Hiatt (1957) appear to indicate that this animal can take up calcium directly from the water and does not need a dietary source of this element. The present investigation with trout indicates that these animals likewise can take up ions directly from the water and do not need a particulate source, at least in regard to zinc. The quantity needed nutritionally, however, must be much less than 0.3 μgm/ml.

Summary

An analysis of the comparative accumulation of radioactive zinc in young rainbow, cutthroat and brook trout reveals that the greatest rate of accumulation of this isotope is found in the brook trout with the least amount being accumulated by the rainbows. A study on the localization of this element showed that in the rainbow trout and the cutthroat, the gill filaments accumulated the greater amount of isotope while in both instances the least amount was discovered in the ventral body wall. Ion uptake in the cutthroat gill was greater than in that of the rainbow with this latter species being found to accumulate only about one-half that discovered in the cutthroat gill.

The rate of accumulation of zinc in the rainbow trout was only 75 percent that found in the brooks. The final total concentration of the ion in 48 hours was found to be greatest in the brook trout, with about 95 percent of this concentration being found in the cutthroats and about 70 percent of the highest concentration seen in the rainbows.

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DEPARTMENT OF ZOOLOGY, UNIVERSITY OF ARIZONA, TUCSON, ARIZONA AND BIOLOGICAL STATION, MONTANA STATE UNIVERSITY, BIGFORK, MONTANA.

Emendated Generic Names in Berg's Classification of Fishes

JOHN C. BRIGGS

THANKS to the efforts of Karl F. Lagler and Carl L. Hubbs, Berg's *Classification of Fishes* (1940) was reprinted at Ann Arbor in 1947 together with an English translation. The result has been a very wide adoption of this work for classroom and general reference use, particularly in North America. In fact, in many institutions it has become almost a "bible" of fish classification especially in areas where much of the primary literature on the subject is not available.

It has gradually become apparent that Berg's classification has a number of disadvantages making it more of a mixed blessing than an unqualified boon to ichthyology. For the most part, it is an uncritical compilation with an excessive splitting of many higher taxonomic categories; yet it is an invaluable guide to the pre-1940 literature and presents many worthwhile illustrations taken from a wide range of publications. A second (posthumous) edition was published in 1955. Unfortunately, this edition does not represent a serious attempt to bring the book up to date for almost all of the significant literature on fish classification which appeared in the intervening 15 years has gone unnoticed. However, as Monod (1958) has pointed out, the 1955 work (of which a German translation is available) has been considerably improved by the addition of some 73 illustrations.

One of the most serious defects in Berg's *Classification*, to which attention has not been called, is the utilization of a number of generic names which represent variations or "improvements" over the spellings as published by the original authors. The generic name, as the mainstay to which specific names are attached and as a foundation for the names of higher categories, is perhaps the most important in systematic literature. It is particularly essential, then, at this taxonomic level, to see that the law of priority and the other applicable International Rules of Zoological Nomenclature are adhered to as closely as possible.

All of the generic misspellings which I have found in the first edition of Berg's work have remained uncorrected in the 1955 edition and, most regrettably, many of these are being perpetuated in other, more recent, classifications as well as checklists and faunal works. In the case of each of the following generic names, I have checked through Matsubara's classification (1955), the Cuban list of Duarte-Bello (1959), and the list of Texas marine fishes by Hoese (1959). This was not done for the purpose of criticising these particular works but to show that such misspellings are being passed on. Presumably, the reason, in most cases, is simply too heavy a reliance upon Berg's *Classification* although, in some instances, the Jordan, Evermann, and Clark checklist (1930) may be to blame.

The genera concerned are listed in alphabetical order. For most of these, it has been possible to consult the original publication in order to make sure of the spelling, the author's name, and the date. Where this was not possible, I have turned to the principal nomenclators such as Sherborn (1902–1933), Jordan (1917–1920), and Neave (1939–1950). I have also attempted to locate the first occurrence of the particular emendation utilized by Berg for apparently none of them originated with his book but were picked up from the older literature.

None of the genera treated herein appear on the *Official List of Generic Names in Zoology* or the *Official Index of Rejected and*

Invalid Generic Names in Zoology as published in 1958 by the International Trust for Zoological Nomenclature.

Acanthoessus Agassiz, 1832

In 1832 Louis Agassiz published in the journal *Neues Jahrbuch Mineralogie* (3:149) a new generic and specific name for the fossil of a spiny, primitive creature originally called an acanthopterygian by Professor Heinrich Bronn of Heidelberg in an earlier (1829) number of the same journal (then called the *Zeitschrift für Mineralogie*). The name given was *Acanthoessus bronnii*. A year later, Agassiz, in his great work *Recherches sur les Poissons Fossils* (2:20), took the liberty of changing his *Acanthoessus* to *Acanthodes*. It is unfortunate that the latter name has remained unquestioned by Berg (1940:374, 1955:56) and almost all subsequent authors for as more of these fossils were studied, their unique structure became apparent so that most ichthyologists now recognize the family Acanthodidae, the order Acanthodiformes, and the class Acanthodii. However, unless a special ruling is made by the International Commission on Zoological Nomenclature, the stem for the preceeding taxa should read Acanthoess.

Aplochiton Jenyns, 1842

Shortly after its original proposal by Jenyns (1842:130), the spelling of this genus was, according to Neave (1939, 2:566), altered by Agassiz (1846) to *Haplochiton*. Jordan (1919: 212) attributes this variation to Albert Günther but it seems reasonable to assume that the latter was merely following Agassiz. *Haplochiton* (and the family Haplochitonidae) is listed in Berg's classification (1940:429, 1955: 177).

Aplodactylus Valenciennes, 1832

As in the case of *Aplochiton*, this is an instance where Agassiz, according to Neave (1939, 2:566), proposed an "improved" spelling (*Haplodactylus*) in his 1846 work (*op. cit.*). *Aplodactylus* was originally described in the *Histoire Naturelle des Poissons* of Cuvier and Valenciennes (8:477). As Bailey (1951:250) has pointed out, this is a situation where two authors clearly divided the task between themselves so that, under the International Rules as they now stand, the new names are to be attributed solely to the author stated to be responsible—in this case, Valenciennes.

Neave (1939, 1:254), Sherborn (1923, Sect. 2:402) and Jordan (1917:137) list the date of publication for *Aplodactylus* as 1831 and the page number in volume eight of the *Histoire Naturelle des Poissons* as 476. However, Sherborn in a later work (1925:600) presented a detailed collation of the publication dates for the above monograph showing that volume eight was actually published in January, 1832. The correct page number in the standard octavo edition is 477. The Agassiz variation of 1846 is utilized by Berg in both editions of his fish classification (1940:477; 1955:238).

Hemiramphus Cuvier, 1817

Cuvier separated this genus from *Esox* in the first edition of *Règne Animal* (1817, 2:186), spelling it "*Hemi-Ramphus*". Most later authors have correctly omitted the hyphen and capitalize only the first letter. According to Neave (1939, 2:612) the variation *Hemirhamphus* was originally introduced by Voigt *in* Cuvier (1832, 2:383). In Jordan, Evermann, and Clark (1930:199) this name is misspelled, in the Voigt manner, twice and listed correctly twice. The same misspelling may be found in both editions of Berg's *Classification* (1940:454, 1955:212) and in the Cuban checklist (Duarte-Bello, 1959:44).

Hiodon Lesueur, 1818

Soon after the proposal of *Hiodon* by Lesueur (1818:364) the spelling, according to Neave (1939, 2:726), was altered to *Hyodon* by Rafinesque (1820:174) in his work on the natural history of the fishes of the Ohio River. The latter spelling is utilized by Berg (1940:434; 1955:186) for both the genus and family (Hyodontidae).

Istiophorus Lacépède, 1802

This genus was introduced by Lacépède in the first edition of his *Histoire Naturelle des Poissons* (1802, 3:374) and spelled as listed above. A change to *Histiophorus* was initiated by Cuvier *in* Cuvier and Valenciennes (1832, 8:293). This was unfortunately adopted by Berg (1940:484; 1955:246), Matsubara (1955: 526), and Duarte-Bello (1959:118).

Kyphosus Lacépède, 1802

This is another genus first described by Lacépède in the *editio princeps* of his famous work (1802, 3:114). This name begins with a *K* in all of the older works and, apparently, the variation *Cyphosus* was introduced by Jordan and Gilbert (1882b:972). It is utilized by Berg (1940:475; 1955:237) in reference to

the family name (Cyphosidae) and by Duarte-Bello (1959:93).

Leiognathus Lacépède, 1803

This genus was spelled as above by Lacépède (1803, 4:448) when he published the original description. The emendation *Liognathus* was apparently introduced by Agassiz in 1846. Its usage has been continued by Berg (1940:475; 1955:236—family name) and Duarte-Bello (1959:84—family name).

Lepidotes Agassiz, 1832

This is another case in which Agassiz named a genus in one publication and then "improved" the spelling in a subsequent work. *Lepidotes* was described, according to Neave (1939, 2:901) and the other nomenclators, in the *Neues Jahrb. Mineral.* (1832:145). Agassiz then proposed the variation *Lepidotus* in his *Recherches sur les Poissons Fossiles* (1833, 2:8) despite the fact that this name was preoccupied by the genus *Lepidotus* of I. de Asso, 1801, also in Pisces. The latter spelling (attributed to Agassiz) may be found in both editions of Berg (1940:411; 1955:143).

Lepisosteus Lacépède, 1803

The above spelling was employed by Lacépède (1803, 5:331) for the original description. According to Neave (1939, 2:901), the emendation to *Lepidosteus* was first made by Koenig (1825:pl. 12). It has been perpetuated by Berg (1940:415; 1955:154), Duarte-Bello (1959: 23), and other modern writers.

Lophotus Giorna, 1809

Although the confusion surrounding the original spelling and date of publication of this genus of crestfishes was cleared up by Goin and Erdman (1951:285), the spelling of the French vernacular (*Lophotes*) continues to be employed, appearing in such works as Berg (1955:223) and Duarte-Bello (1959:23).

Lutjanus Bloch, 1790

The name of this large, worldwide genus is usually misspelled *Lutianus*. I have examined a copy of the first edition of Bloch (1790:105) and find that in the text where the genus is described and for each of the 15 included species, the spelling is consistently *Lutjanus*. However, in the atlas which accompanies this work it can be seen that several of the plates are labelled *Lutianus*. This is probably the origin of the latter variation although its early use by Cuvier (1798:357) undoubtedly had considerable influence. *Lutianus* is employed by Jordan, Evermann, and Clark (1930:324), both editions of Berg (1940:475; 1955:236), Hoese (1959:334), Duarte-Bello (1959:80), and many other modern works.

Mochokus Joannis, 1835

The nomenclatural works of Sherborn, Neave, and Jordan agree that Joannis described *Mochokus* in 1835 (5:pl. 8). Apparently, Günther (1864, 5:217) is responsible for the change to *Mochocus*. Günther's variation was utilized by Berg (1940:448; 1955:204) in the sense of a family name (Mochocidae) equivalent to the Synodontidae. More recently, as Myers (1960:79) has pointed out, this erroneous spelling has appeared in Poll's *Les Genres des Poissons d'Eaue Douce de l'Afrique* (1957:121).

Noemacheilus Hasselt, 1823

Although all three principal nomenclators (Sherborn, Jordan, and Neave) agree that this genus was described by van Hasselt (1823: 133) in his publication on the fishes of Java, their spelling (*Nemacheilus*) is apparently wrong for Schultz *in* Smith (1945:303) has stated that the original version is *Noemacheilus*. Günther (1868, 7:347) is probably responsible for the change to *Nemachilus*, a spelling which is utilized by Berg (1940:446; 1955:200) and Matsubara (1955:289).

Ogcocephalus Fischer, 1813

Although I have not had the opportunity to examine the original publication, the nomenclators (Sherborn, Jordan and Neave) agree as to the spelling and date of appearance of *Ogcocephalus* (Fischer, 1813:78). Jordan, Evermann, and Clark (1930:506) list in the synonymy of *Ogcocephalus*, the name *Oncocephalus* attributing it to Theodore Gill as a "corrected spelling." For some reason, this variation was picked up by Berg and carried in both editions (1940:499; 1955:264) in reference to the family name of the batfishes (Oncocephalidae). Duarte-Bello (1959:143) has followed Berg.

Ophicephalus Bloch, 1793

This genus was first described in part seven of Bloch's *Naturgeschichte der Ausländischen Fische* (1793:137). In 1822, Hamilton (Buchanan) (p. 60) altered the spelling to *Ophiocephalus*. This version has been used by many modern writers such as Berg (1940:471; 1955: 232) despite the fact that the genus *Channa*

of Scopoli, 1777, as Myers and Shapovalov (1931:33–37) have pointed out, has priority over both Bloch's and Hamilton's names.

Ophichthus Ahl, 1789

The nomenclature of this genus was discussed in a publication by Jordan and Gilbert (1882a:648) in which a portion of the rare, original paper by Ahl (1789) was reprinted. From this evidence, there is little doubt that the genus was spelled *Ophichthus* and that the date was indeed 1789 (although Jordan in his *Genera of Fishes*, 1917:44, gives 1787). The common variation *Ophichthys* was apparently introduced by Swainson (1839, 2:336). It is employed by Berg (1940:452; 1955:208—family Ophichthyidae) and appears in the recent checklist of Duarte-Bello (1959:39—family name).

Opistognathus Cuvier, 1817

Although Jordan (1917:101) gives credit to Oken for the latinization of what Jordan called the "Les Opisthognathes" of Cuvier, 1817, I find that Cuvier (1817, 2:252) provided his own latinization (*Opistognathus*) and, furthermore, that the stem of the French vernacular name has the same spelling—"Les Opistognathes." The variation *Opisthognathus* was apparently introduced by Valenciennes *in* Cuvier and Valenciennes (1836, 11:498) and has been almost universally followed since that time appearing in such works as Jordan, Evermann, and Clark (1930:452), both editions of Berg's classification (1940: 477; 1955:239—family Opisthognathidae), Matsubara (1955:697—family name), Briggs (1958:289), and the recent Cuban checklist of Duarte-Bello (1959:106).

Oplegnathus Richardson, 1840

The original description of this genus, spelled as above, was published by Richardson (1840:27). The following year, according to Neave (1940, 3:446), it was spelled *Oplectognathus* by Troschel (1841:136). Richardson himself (1842:71) apparently made the "correction" to *Hoplegnathus* which was picked up by Berg (1940:476; 1955:237).

Stylephorus Shaw, 1791

According to the nomenclators, Sherborn (1902, sect. 1:940) Jordan (1917:50), and Neave (1940, 4:340), *Stylephorus* was first described in the *Transactions of the Linnaean Society of London* (Shaw, 1791:90). It was spelled *Stylephonus* by Bloch and Schneider (1801:519) and *Stylophorus* by Berthold *in* Latreille (1827:597). Berthold's version may be found in both editions of Berg (1940:464; 1955:223), Matsubara's important work (1955: 465), and the Cuban list of Duarte-Bello (1959:53).

Synanceja Bloch and Schneider, 1801

Synanceja was described in the *Systema Ichthyologiae Iconibus CX Illustratum* of Bloch and Schneider (1801:194). Cloquet (1827:440) then emended the spelling to *Synanceia*, Gray and Hardwicke (1830, 1:pl. 97) changed it to *Synanacea*, and finally, according to Sherborn (1931, sect. 2:6351), Agassiz (1846) preferred *Synancia*. Both editions of Berg (1940:488; 1955:251) follow Cloquet's spelling for the family name (Synanceidae) and Matsubara (1955:1093) does the same on both the generic and family levels.

Synbranchus Bloch, 1795

Bloch (1795, pt. 9:86) originally described this genus. According to Neave (1940, 4:360), Müller (1841:245) was responsible for the alteration to *Symbranchus*. Unfortunately, the latter was picked up by Berg and published in his classification (1940:472; 1955:233). Apparently, this is the reason for its utilization by both Matsubara (1955:1328) and Duarte-Bello (1959:61).

Tetraodon Linnaeus, 1758

This genus dates from the tenth edition of the *Systema Naturae* (1758:332). However, an alternative spelling (*Tetrodon*) was introduced at an early date by Linnaeus himself in the twelfth edition of his famous work (1766:410). It was picked up by Berg (1940: 496; 1955:261—family name) and is perpetuated by Duarte-Bello (1959:137) as well as the new Canadian checklist of McAllister (1960: 52).

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INSTITUTE OF FISHERIES, UNIVERSITY OF BRITISH COLUMIBA, VANCOUVER 8, B. C. CANADA.

The Bornean Cyprinoid Fishes of the Genus *Gastromyzon* Günther

ROBERT F. INGER AND CHIN PHUI KONG

THE rich freshwater fauna of Borneo includes several genera of cyprinoid fishes adapted to life in very swift water. Probably the most specialized of these are the species placed in the genus *Gastromyzon* Günther (*sens. lat.*), which occurs only in Borneo.

In plan view these fishes have a streamlined, teardrop shape; the snout is broadly rounded, the head relatively wide, and the body tapered. In profile the head slopes gradually upward, and the highest point on the body lies just ahead of the dorsal fin. The body depth, however, is not great. Below, these fishes are perfectly flat. The paired fins are horizontally disposed and form lateral extensions of the ventral surface.

The entire ventral surface has been converted into a disk, the position and orientation of the horizontal fins making them part of this construction. Contributing to this development is the fusion of the pelvic fins under the body so that they form a semicircle at the end of the disk. A flat extension of the body wall, forming a flap between the pectoral and pelvic fins along the line of juncture of side and belly, completes the disk. A small extension of this flap overlies the beginning of the pelvic fin.

Fishes living in swift currents have adopted several methods of maintaining position other than mere power in swimming. *Gastromyzon* utilizes a clinging technique and the entire body form is organized around the requirements of this habit (Hora, 1932). The fish usually faces upstream and clings to a rock by means of the ventral disk. The streamlined plan reduces the exposure of the body to the force of the current. The horizontal arrangement of the paired fins and their position low on the sides increases the surface of the ventral disk and makes it more effective. Since the underside of many rays of the pectorals and pelvics have special adhesive or frictional surfaces (Hora, 1932), these fins provide a frictional component to the action of the disk.

The pectoral fins of *Gastromyzon* are modified from the usual cyprinoid form not only by their position, but also by their size and functional subdivision. Among the cyprinoid fishes of Southeast Asia, Sumatra, Java, and Borneo, the pectoral fins usually have 13 to

16 branched rays all very much alike except for length. Three Bornean fishes (*Protomyzon whiteheadi, P. borneensis,* and *Progastromyzon griswoldi*) related to *Gastromyzon* have 21 or 22 branched rays (Silas, 1953). *Gastromyzon* has 21 to 28.

Only the first two-thirds of the pectoral fin of *Gastromyzon* takes part in the clinging device. The last third is curved up against the side of the body and by its constant fanning movements helps propel the water issuing from the gill opening. Hora (1932) said that the function of these fanning movements is to divert the current from the ventral surface of the fish.

The pelvic fin of *Gastromyzon* is also much larger than it usually is in cyprinoid fishes. In the approximately 200–250 species of cyprinoids in Java, Sumatra, and Borneo, the number of branched pelvic rays does not exceed 12 (usually not more than 8) except in *Gastromyzon* in which it varies from 14 to 24.

The other external features related to the basic adaptation is the position and form of the gill opening (Fig. 4). In *Gastromyzon* and some related Bornean fishes the opening is small and restricted to the side of the body above the pectoral fin, whereas the gill opening of most cyprinoids is long and extends below the pectoral and forward under the head. If *Gastromyzon* had the gill opening of the latter sort, respiratory movements would lead a current of water under the ventral disk and interfere with its suctorial action.

Gastromyzon is a characteristic inhabitant of small, clear, and swift rain forest streams wherever these pass over a boulder-strewn bottom. Though one usually associates that situation with moderate elevations, such streams occur in many places in Borneo within a few hundred feet of sea level. We have caught *Gastromyzon* in low hilly country at the junction of the Sungai Putai and the Baleh River, Sarawak, and in the low Kinabatangan basin of North Borneo. It has also been collected as high as 1,350 meters on Mount Kina Balu.

In the swift, clear water, one first sees *Gastromyzon*, dark greenish or blackish fishes 50 to 100 mm. long, darting from rock to rock or moving slowly over the surfaces of boulders. They are not active fishes but spend most of the time clinging to rocks. These fishes graze on algae growing on the substrate, and if they are not disturbed, one can observe them moving slowly over the surface of boulders leaving narrow naked trails from which they have scraped the algae.

A common defensive behavior of *Gastromyzon* is to move around a boulder so that the rock always lies between the fish and the would-be observer. In fact, this behavior is so fixed that the fish can be caught by slowly lifting a rock to which it is attached and dropping the rock into a dip net. Despite their relatively small eyes, these fishes have good vision and are easily startled by a person walking along the bank at a distance of about 3 meters.

Only one of the two previously known species was thought to be common. *Gastromyzon borneensis* has been reported from many rivers in widely separated areas of Borneo (Fig. 1) and at least one large collection has been made on Mount Kina Balu (Silas, 1953). The second species (*G. nieuwenhuisi*) has been known only from a single specimen since it was first described (Popta, 1905) and has been considered a rare fish. Yet more than 100 were caught at one spot along a small stream draining into the Baleh River (Fig. 2) in 1956. The additional species to be described below were also taken in moderate numbers in the same general area. Evidently, the explanation for the rarity of these fishes in museum collections is simply lack of collecting effort, lack of the proper collecting technique, or both.

Fig. 1. Distribution of *Gastromyzon borneensis* and *G. nieuwenhuisi* in Borneo. Solid triangle, type locality of *borneensis*. Open triangles, other records of *borneensis*. Star, type locality of *nieuwenhuisi*. Barred rectangle is area shown in Fig. 2.

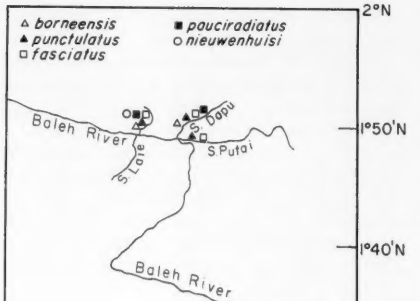

Fig. 2. Distribution of species of *Gastromyzon* in upper Baleh River basin, Sarawak.

Generic Limits

Species grouped here under *Gastromyzon* were originally described under two genera, the second being *Neogastromyzon* Popta. *Neogastromyzon* was placed in the synonymy of *Gastromyzon* by Weber and de Beaufort (1916), but recognized as a distinct genus by Hora (1932) and Silas (1953). The type species of the two supposed genera differ somewhat in body proportions and fin ray counts (see below). They also differ in the arrangement of mouth parts. In *G. borneensis*, as in *G. fasciatus* and *G. punctulatus* (Figs. 3A and 3B), the four rostral barbels originate posterior to an infrarostral groove, arising from the forward edge of a prelabial "pad". In *G. nieuwenhuisi* the barbels originate just anterior to the infrarostral groove and there is no prelabial pad (Fig. 3C).

Comparable differences in mouth parts have been used to distinguish other dubious genera of gastromyzontids (e.g., *Protomyzon* and *Progastromyzon*). But to recognize two genera on the grounds of structures of unknown ecological and phylogenetic significance, while ignoring the detailed similarity in an adaptive complex—the ventral disk—that clearly delineates the phylogenetic development of the group, is to place the definition of genera on exactly the same procedural basis as the definition of species and, thus, to commit an important taxonomic error (Inger, 1958).

The possibility of convergence in the ventral disk must be considered before overwhelming taxonomic importance is attached to it. Apart from the species discussed here, a clinging disk formed by fused pelvics and broad, horizontal pectorals has developed in three other genera of the ecologically similar families, Homalopteridae and Gastromyzontidae (Silas, 1953). These three, *Beaufortia*, *Sinogastromyzon*, and *Metahomaloptera*, occur in Indo-China, China, and Formosa. In none of them is the gap between pectoral and pelvic fins bridged by a flap of the body wall as in *Gastromyzon*. That such a refinement of the ventral disk should have developed only in Bornean species is too much of a coincidence to lay to convergence. It is far more likely that this development represents a common phylogeny.

Definition of Species

Large collections of *Gastromyzon* were obtained in two small tributaries of the Baleh River (in central Sarawak) separated by less than 10 kilometers (Fig. 2). Included in these

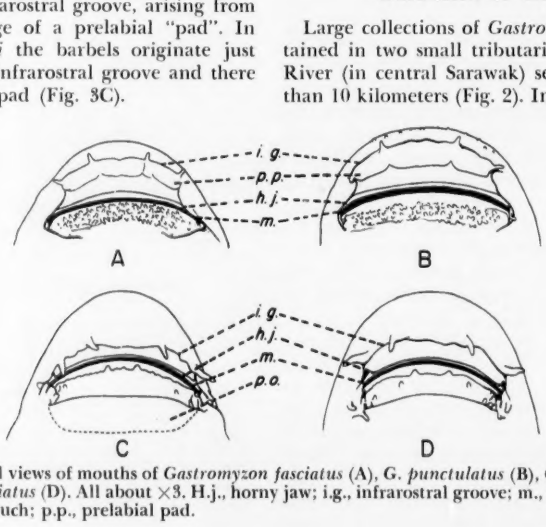

Fig. 3. Ventral views of mouths of *Gastromyzon fasciatus* (A), *G. punctulatus* (B), *G. nieuwenhuisi* (C), *G. pauciradiatus* (D). All about ×3. H.j., horny jaw; i.g., infrarostral groove; m., mouth opening; p.o., postoral pouch; p.p., prelabial pad.

collections were fishes of two general body forms, a slender type (*"Neogastromyzon"*) and a broad type (*"Gastromyzon"*). As already noted, the two types differ in their mouth parts. Fishes of the two body types also differ in the separation of pelvic and anal fins. In the slender type the distance between the margin of the pelvic and the anal fin is equal to twice the eye diameter. In the broad-bodied type the distance between these fins is less than the diameter of the eye; many individuals even have the pelvic reaching the anal.

Each type is represented in these collections by more than one form. The slender forms differ from one another in the ornamentation of the lower lip, one (*pauciradiatus*) having a fringe-like cluster of papillae at the corner of the lower lip and the other (*nieuwenhuisi*) not (Fig. 3). Dividing the specimens on the basis of this character yields samples differing in the numbers of lateral-line pores and branched pectoral and pelvic rays (Table 1). One form (*nieuwenhuisi*) has a deep postoral pouch (Fig. 3C), the other does not (Fig. 3D). The suprapelvic flap, an extension of the modified body wall between the pectoral and pelvic fins, is about one and one-half times the eye diameter in *nieuwenhuisi* (0.055–0.093 of standard length; median 0.070) but usually less than eye diameter in *pauciradiatus* (0.026–0.047; median 0.032). The gill opening is larger in *pauciradiatus* (0.042–0.060 of standard length; median 0.050) than in *nieuwenhuisi* (0.032–0.049; median 0.039). The differences in both proportions are statistically significant at the $P = 0.001$ level (Mann-Whitney U test used, see Siegel, 1956).

The broad-bodied *Gastromyzon* from the Baleh collections fall into two groups on the basis of opercular shape. One group has a small gill opening and an almost vertical opercular border and the other a large gill opening and a sinuate opercular margin (Fig. 4). The second group can be divided again into a form (*fasciatus*) having broad dark vertical bars separated by narrow light spaces and one (*punctulatus*) having small, round light spots on a dark background on the head and anterior portion of the body. These last two differ significantly in the number of lateral-line pores and number of branched pelvic rays (Table 2). The form (*borneensis*) having the small gill opening has fewer pores and probably fewer pectoral rays than the other two. It also has fewer pelvic rays than *fasciatus* and differs further from *punctulatus* in having dark vermiculations on the head.

TABLE 1. FREQUENCY DISTRIBUTION OF NARROW-BODIED SPECIES OF *Gastromyzon* FROM THE BALEH RIVER BASIN, CENTRAL SARAWAK WITH RESPECT TO THREE CHARACTERS

Species	Branched pelvic rays							
	14	15	16	17	18	19	20	21
nieuwenhuisi	—	—	—	2	8	11	3	1
pauciradiatus	5	20	—	—	—	—	—	—

	Branched pectoral rays				
	21	22	23	24	25
nieuwenhuisi	—	2	15	7	1
pauciradiatus	6	13	2	—	—

	Lateral-line pores							
	55–57	58–60	61–63	64–66	67–69	70–72	73–75	76–78
nieuwenhuisi	—	—	3	3	4	5	4	1
pauciradiatus	3	7	8	—	—	—	—	—

A shallow groove extending from the lower corner of the gill opening to the anterior base of the pectoral fin is found in all specimens of *fasciatus* (standard lengths to 67.0 mm.). A similar groove occurs only in small (under 35 mm.) *punctulatus* but not in any *borneensis* (Table 2). The three forms also differ in relative length of the gill opening and in relative head width (Table 3).

The preceding comparisons have been based on fishes of approximately the same size range (*ca.* 25–60 mm. standard length), including females with ripe ova in four of the five forms. Consequently the differences among these forms are not attributable to ontogenetic changes. Given so many morphological distinctions and their sympatric relationships, the five types must be regarded as separate species.

The five species differ in degree of specialization. As a common pattern of the Cyprinoidea is a large gill opening extending below the base of the pectoral, it is reasonable to assume that within the Gastromyzontidae a long gill opening is less specialized and more primitive than a small one. On functional grounds (see above), a small gill opening restricted to the dorsolateral surface is more specialized than a longer one reaching the base of the pectoral. None of the five

species of *Gastromyzon* has a gill opening reaching the pectoral, but the groove that extends ventrally from the opening in *fasciatus* represent that former ventral portion

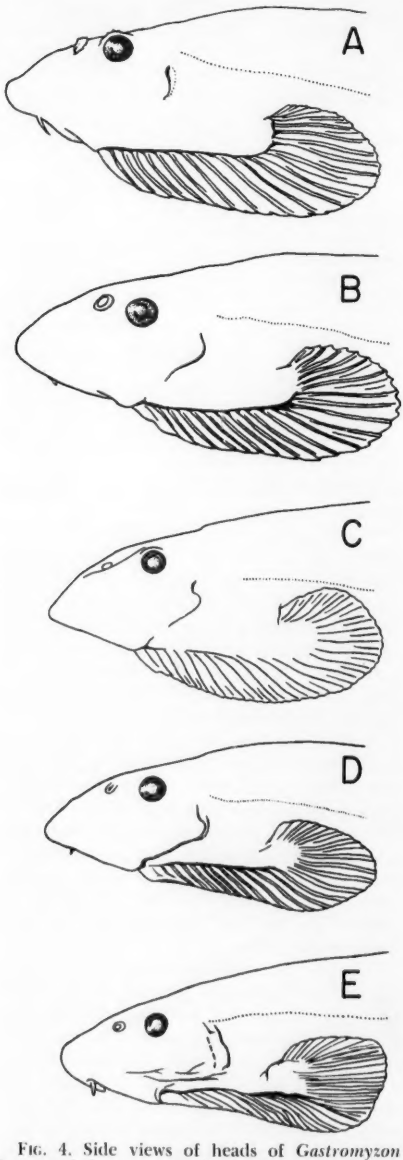

FIG. 4. Side views of heads of *Gastromyzon borneensis* from eastern North Borneo (A), *borneensis* from central Sarawak (B), *G. punctulatus* (C), *G. fasciatus* (D), *G. pauciradiatus* (E). All about ×2.

TABLE 2. FREQUENCY DISTRIBUTION OF BROAD-BODIED SPECIES OF *Gastromyzon* FROM THE BALEH RIVER BASIN, CENTRAL SARAWAK, WITH RESPECT TO FOUR CHARACTERS

Species	Lateral-line pores									
	40–42	43–45	46–48	49–51	52–54	55–57	58–60	61–63	64–66	67–69
borneensis	3	3	3	—	—	—	—	—	—	—
fasciatus	—	—	—	—	—	—	—	4	7	2
punctulatus	—	3	2	1	6	5	—	—	—	—

	Branched pelvic rays						
	18	19	20	21	22	23	24
borneensis	2	2	3	—	—	—	—
fasciatus	—	—	1	6	6	—	1
punctulatus	3	3	2	—	—	—	—

	Branched pectoral rays					
	23	24	25	26	27	28
borneensis	1	5	1	—	—	—
fasciatus	—	—	—	7	6	1
punctulatus	1	2	2	3	3	1

Standard length (mm.)	Groove from gill opening					
	fasciatus		punctulatus		borneensis	
	present	absent	present	absent	present	absent
–30	1	0	4	2	0	2
31–40	—	—	3	2	0	1
41–50	4	0	0	4	0	2
51–	8	0	0	4	0	4

of the opening. *Gastromyzon fasciatus*, therefore, is the least specialized in this character. Probably, *punctulatus*, in which the groove is evident in juvenile specimens only, should be placed next in this series. The other three species represent the most specialized stage, in which the groove is not present even in specimens smaller than 30 mm. In terms of the relative length of the gill opening, *punctulatus* (median[1] 0.078) and *fasciatus* (0.072) are the least specialized, *borneensis* (0.054) and *pauciradiatus* (0.045) more specialized, and *nieuwenhuisi* (0.039) the most

[1] As means are appropriate only for measurements on an interval scale, they should not be used for body proportions, which probably at best are measurements on an ordinal scale (see discussion in Siegel, 1956, pp. 21 ff). Means are used in this paper only for those measurements (e.g., fin ray counts) that are on an interval scale.

TABLE 3. COMPARISON OF BODY PROPORTIONS IN BROAD-BODIED SPECIES OF *Gastromyzon* FROM THE BALEH RIVER, CENTRAL SARAWAK. PROPORTIONS GIVEN IN THOUSANDTHS OF STANDARD LENGTH

Species	No.	Gill opening		Head width	
		Range	Median	Range	Median
borneensis	9	48–67	56	258–304	275
puntulatus	19	59–92	78	297–339	314
fasciatus	17	63–82	72	275–308	291
		$H^1 = 18.48$	$P < 0.001$	$H^1 = 29.66$	$P < 0.001$

[1] H of Kruskal-Wallis analysis of variance (Siegel, 1956).

specialized. In this discussion and in the descriptions that follow, all numerical body proportions are given in terms of standard length, the distance from the tip of the snout to the caudal flexure.

In view of the low number of rays in the paired fins of cyprinoids generally (see above), we consider a high number of rays more specialized than a low number. In these counts *pauciradiatus* (mean of pectorals i,21.8, of pelvics i,14.8) is the least specialized, *nieuwenhuisi* (pectorals i,23.3, pelvics i,18.7) next, *borneensis* (pectorals i,24.3, pelvics i,19.0) and *punctulatus* (pectorals i,25.0, pelvics i,19.0) somewhat more advanced, and *fasciatus* (pectorals i,26.5, pelvics i,21.5) the most specialized.

KEY TO SPECIES OF *GASTROMYZON*

1A. Head width just anterior to pectorals 5 or more times in standard length; edge of pelvics separated from anal fin by more than diameter of eye . . . . . 2.

B. Head width at most 4 times in standard length; edge of pelvics separated from anal fin by less than diameter of eye or reaching anal . . . . . 3.

2A. Pelvic fins with 14–15 branched rays; no postoral pouch; scales between pelvic and lateral line 7–9; suprapelvic flap shorter than eye diameter *pauciradiatus.*

B. Pelvic fins with 17–21 branched rays (usually 18–19); a deep postoral pouch; scales between pelvic and lateral line 10–13; suprapelvic flap longer than eye diameter . . . . . *nieuwenhuisi.*

3A. A distinct groove between lower corner of gill opening and front of pectoral base 4.

B. No groove between lower corner of gill opening and front of pectoral base 5.

4A. With broad, dark, vertical bands and narrow light intervals . . . . . *fasciatus.*

B. Not banded; top of head and vertebral area with small, round, light spots in a dark network . . . . . *punctulatus.*

5A. Top of head and vertebral area with small round light spots in a dark network *punctulatus.*

B. Top of head with dark spots in a light network, or no pattern visible *borneensis.*

Gastromyzon borneensis Günther

Gastromyzon borneensis Günther, 1874, Ann. Mag. Nat. Hist., (4), 14:454—Mengalong River, North Borneo.

Material examined.—North Borneo (32), Sarawak (22).

Diagnosis.—A relatively large species of *Gastromyzon*; head width less than 4 in standard length; pelvics usually overlapping anal, otherwise distance between edge of pelvics and anal less than diameter of eye;

TABLE 4. GEOGRAPHIC VARIATION OF *Gastromyzon borneensis* IN RELATIVE LENGTH OF DISTANCE FROM TIP OF SNOUT TO END OF PELVIC (AS THOUSANDTHS OF STANDARD LENGTH)

	No.	Range	Median
Eastern North Borneo:			
Deramakot	9	833–869	844
Western North Borneo:			
Tambunan	5	657–786	781
Keningau	4	758–804	792
Kota Belud	3	848–865	849
Sarawak:			
Trusan River	2	840–883	860
Akah River	3	829–863	836
Baleh River	9	761–829	801

rostral barbels posterior to infrarostral groove (as in Fig. 3A and B); no groove between lower corner of gill opening and origin of pectoral; body dark, usually with narrow vertical light bars; head dark with narrow, light vermiculation; dorsal and caudal fins with narrow dark checks on rays.

Descriptive notes.—Dorsal iii,7–8 (9 of 32 have 7 branched rays); pectoral i,23–26 (mean i,24.3; N = 29); pelvic i,18–21 (mean i,19.0; N = 29); anal ii,4–5 (6 of 24 have 5 branched rays); lateral-line pores 40–58 (mean 51.8, N = 36).

Total length 26–91 mm.; standard length 20.6–75.1 mm.; head width (measured just anterior to pectoral base) 0.237–0.329 (median 0.287; N = 35); eye 0.035–0.059, becoming progressively smaller as standard length increases; gill opening 0.042–0.070 (median 0.054; N = 35); distance between snout and posterior edge of pelvics 0.657–0.883 (median 0.829; N = 35).

Top of head and dorsal base of pectoral with dark brownish spots separated by a light network; body dark with light vertical bands of varying width.

Mature fishes (50–75 mm.) of both sexes have small tubercles on dorsal surfaces of head and pectoral fins. The tubercles are larger and more dense on the tip of snout.

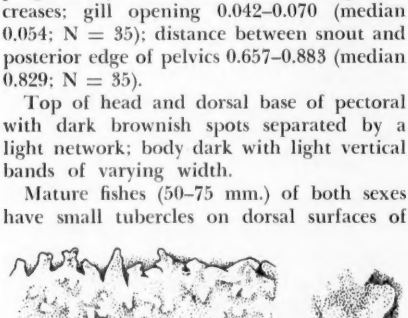

Fig. 5. Papillae of posterior lip of *Gastromyzon punctulatus* (A) and *G. borneensis* (B–D). B from central Sarawak, C from eastern North Borneo, D from western North Borneo. Left column, sections of posterior lips; right column, enlarged individual papillae.

Geographic variation.—The fishes examined are from four areas of Borneo: (1) the Baleh River basin in central Sarawak, (2) the Akah and Trusan rivers of northern Sarawak, (3) western North Borneo, and (4) eastern North Borneo. The Trusan River fishes, collected about 80 kilometers south of the type locality, do not differ appreciably from several collected at Kota Belud, 165 kilometers north of the type locality. We assume, therefore, that these two series do not differ from the topotypic population.

The fleshy dorsal part of the base of the pectoral fin is scaleless throughout its length in fishes from Sarawak and western North Borneo, but has scales on its posterior half in fishes from eastern North Borneo. The number of pores in the lateral line is smaller in fishes from the Baleh River, central Sarawak (40–47) than in all other *borneensis* (52–58). The gill opening in the central Sarawak fishes has more curvature than it does in the others.

Papillae on the lower lip are strongly fringed in fishes from central Sarawak (Fig. 5B), weekly fringed in those from northern Sarawak and eastern North Borneo (Fig. 5C), and not fringed at all in those from western North Borneo (Fig. 5D).

A small series from Tambunan, North Borneo, differs from the others in having the edge of the pelvic separated from the anal fin by a distance equal to the diameter of the eye. The distance from the snout to the end of the pelvic (as thousandths of standard length) varies as follows in the several samples:

Localities.—**North Borneo:** Beaufort District, Mengalong River (Günther, 1874); Jesselton District, Bundu Tuhan; Keningau District, Purutan River; Kinabatangan District, Deramakot, Bukit Kretam; Kota Belud District, Tempasuk River; Kudat District, Bongon; Tambunan District, Kiangaran River. **Sarawak:** First Division, Sadong River (Hora, 1950); Third Division, Mount Dulit (Weber and de Beaufort, 1916), tributary (Sungai Dapu) of Baleh River near mouth of Sungai Putai, tributary of Baleh River opposite Sungai Laie; Fourth Division, Meligong on Akah River; Fifth Division, Lawas, Pa Brayong on Trusan River. **Indonesian Borneo:** Bo, Bluu, and Howong Rivers (tributaries of Mahakam River), Bongan River (tributary of Kapuas River), Kajan River (all from Weber and de Beaufort, 1916).

Gastromyzon punctulatus *sp. n.*

Holotype.—Chicago Natural History Museum number 68116, collected in the Sungai Dapu, a tributary of the Baleh River near the mouth of the Sungai Putai, Third Division, Sarawak, on August 8, 1956, by Robert F. Inger.

Paratypes.—All from the upper Baleh River basin, Third Division, Sarawak. CNHM 68117 (11) from type locality. CNHM 68118 (6), tributary of Baleh River opposite Sungai Laie. CNHM 68124, mouth of Sungai Putai.

Diagnosis.—A moderate-sized species of *Gastromyzon*; head width less than 4 in standard length; pelvics usually not overlapping anal, distance between edge of pelvics and anal less than eye diameter; rostral barbels posterior to infrarostral groove; groove between ventral corner of gill opening and origin of pectoral absent in adults, sometimes present in specimens smaller than 35 mm. standard length; body without light vertical bars; top of head and vertebral region dark with numerous small, round light spots.

Description (data on holotype in parentheses).—Dorsal iii, 7–8 (iii,8); pectoral i,23–26 (i,25) (mean i,25.0; N = 19); pelvic i,18–21 (i,18) (mean i,19.0; N = 19); anal I,i,4–5 (I,i,4); lateral-line pores 43–57 (54) (mean 51.2; N = 17).

Total length 29–72 mm. (72); standard length 20.9–57.5 mm. (57.5); head width anterior to insertion of pectorals 0.297–0.339 (0.314) (median 0.314; N = 19); gill opening 0.059–0.092 (0.085) (median 0.078; N = 19); eye 0.036–0.057 (0.036), decreasing as standard length increases.

Head depressed; body wide, flattened below, compressed behind dorsal fin; dorsal profile convex; greatest depth just before dorsal fin; ventral profile straight; snout broadly rounded; width of head before insertion of pectorals 3.0–3.3 in standard length; posterior margin of opercle deeply notched, a distinct posterior projection ventrally; no groove from gill opening to origin of pectoral in adults, sometimes present in specimens of less than 35 mm. standard length; eye small, subequal to distance between eye and nostril and to distance between eye and top of gill opening, about 3.5 times in interorbital.

Mouth ventral (Fig. 3B); an infrarostral groove; four rostral barbels in a broad prelabial pad, barbels posterior to infrarostral groove; a barbel at each corner of mouth; upper lip separated from prelabial pad by a shallow groove; lower lip papillose (Fig. 5A); specimens larger than 35 mm. have papillae in a shallow groove behind the lower lip.

Pectorals low on side, horizontal anteriorly, posterior quarter vertical, origin below anterior margin of eye; a broad ventrolateral flap between pectoral and pelvic fins ending in a scaleless adipose flap above base of pelvic fin; length of suprapelvic flap (measured along free dorsal border) usually less than distance between eye and edge of opercular membrane; free edge of fused pelvics separated from anal fin by distance shorter than eye diameter; origin of dorsal above end of pectoral, margin of dorsal straight; tip of adpressed anal usually reaching caudal; caudal fin obliquely truncate, ventral rays longest.

Lateral line sloping downward from above gill opening to midlateral region; fleshy base of pectoral scaleless; ventrolateral flap with broad scaleless area laterally; suprapelvic flap scaleless; ventral disk without scales.

Color in life dark greenish brown above with numerous small light spots; in alcohol dark purplish brown with light spots; dorsal fin with colorless margin and two longitudinal black bands, the outer one narrower; caudal fin with three or four narrow, vertical black bands, subequal in width to light interspaces; pectoral and pelvic fins dusky above with very dark basal bands and dark, narrow, inframarginal bands; ventral surface of body and paired fins cream-colored.

Mature fishes (40–55 mm.) of both sexes have small tubercles on dorsal surfaces of head and pectoral fins. The tubercles are largest and most dense on the tip of the snout.

Comparisons.—See above, p. 168–171.

Gastromyzon fasciatus *sp. n.*

Holotype.—Chicago Natural History Museum number 68119, collected in the Sungai Dapu, a tributary of the Baleh River near the mouth of the Sungai Putai, Third Division, Sarawak, on August 8, 1956, by Robert F. Inger.

Paratypes.—All from the upper Baleh River basin, Third Division, Sarawak. CNHM 68115 (28 specimens) collected with the holotype; 68120 (4), tributary of Baleh River opposite Sungai Laie; 68125, mouth of Sungai Putai.

Diagnosis.—A species of *Gastromyzon* with

head width less than 4 times in standard length; edge of pelvics separated from anal by less than diameter of eye; fleshy dorsal base of pectoral fin with a broad scaleless border; a distinct groove between lower corner of gill opening and origin of pectoral; body with narrow vertical light bands; more than 60 pores in lateral line; 20 or more branched ventral rays.

Description (data on holotype in parentheses).—Dorsal iii,8 (iii,8) (N = 17); pectoral i,26–28 (i,27) (mean i,26.5; N = 17); pelvic i,20–24 (i,22) (mean i,21.5; N = 17); anal I,i,5 (I,i,5); lateral-line pores 60–67 (64) (mean 63.6; N = 17).

Total length 26–83 mm. (83); standard length 19.5–67.0 mm. (67.0); head width anterior to insertion of pectorals 0.275–0.308 (0.276) (median 0.291; N = 17); gill opening 0.063–0.082 (0.070) (median 0.072; N = 17); eye 0.043–0.056 (0.043) decreasing as standard length increases.

Head depressed; body wide, flattened below, becoming compressed behind origin of dorsal; dorsal profile rising in convex arc to dorsal origin, sloping to caudal; ventral profiles straight.

Snout broadly rounded; width of head just before insertion of pectorals 3.25–3.5 in standard length; posterior margin of opercle deeply concave, a distinct posterior projection ventrally; a distinct oblique groove from gill opening forward to beginning of pectoral; anterior and posterior nostrils separated by valvular flap; anterior nostril twice as far from snout as from eye; distance between pairs of nostrils about two-thirds interorbital; eye small, varying inversely with standard length, about 3 times in interorbital, 6–7 times in head length of 60 mm. fish, completely above level of gill opening; mouth ventral (Fig. 3A); an infrarostral groove; four rostral barbels in a broad prelabial pad of skin, barbels posterior to infrarostral groove; a barbel at corner of mouth; upper lip separated from prelabial pad by weak transverse groove; lip partly overlapping upper horny jaw; lower lip papillose; papillae of lower lip fringed or simple, the degree of fringing gradually reduced from center of lip laterad.

Pectorals horizontal, inserted below anterior margin of eye, posterior third of fins vertical; a broad ventrolateral flap between pectoral and pelvic, forming a broad suprapelvic adipose flap over anterior portion of that fin; length of suprapelvic flap (measured along free dorsal edge) equal to distance between eye and posterior projection of opercular flap; fused pelvics horizontal, posterior margin reaching anal origin or separated from it by less than eye diameter; origin of dorsal fin opposite end of pectoral, margin of fin straight; anal fin pointed, first branched ray longest; first two anal rays unbranched, much thicker than remainder of fin, first ray spinose and four-fifths length of second; tip of adpressed anal usually reaching caudal; caudal slightly emarginate or truncate oblique; lower rays longer than upper rays.

Lateral line sloping downward from above opercle to above ventral origin, horizontal in mid-lateral line thereafter; fleshy base of pectoral without scales; ventrolateral flap with broad scaleless margin, free portion above pelvic entirely scaleless; ventral disk without scales.

Color in life dark green; head usually with small pale elongate spots; body with narrow (1–2 scales wide), vertical, light bars and a few round spots; in alcohol, ground color dark purplish brown; ventral surface immaculate cream-colored; dorsal fin membrane colorless, rays dark; pectoral dark above, membrane colorless only in posterior quarter; pelvic dark in basal two-thirds, membranes colorless distally, indications of light band splitting dark area; anal fin with colorless membrane, rays dark; caudal fin with two or three broad vertical dark bands on rays, membrane colorless.

Mature fishes (50–65 mm.) of both sexes have small tubercles on dorsal surfaces of head, pectoral fins, and sometimes on anterior rays of pelvic fins. The tubercles are largest on tip of snout.

Comparisons.—See above, p. 168–171

Gastromyzon pauciradiatus sp. n.

Holotype.—Chicago Natural History Museum number 68121 from a small, unnamed tributary of the Baleh River opposite the Sungai Laie, Third Division, Sarawak. Collected August 5, 1956, by Robert F. Inger.

Paratypes.—All from the upper Baleh River basin, Third Division, Sarawak. CNHM 68122 (23 specimens), collected with the holotype; 68123, Sungai Dapu.

Diagnosis.—A species of *Gastromyzon* with head width more than 5 times in standard length; edge of pelvic fin separated from anal fin by at least twice eye diameter; rostral barbels originating anterior to infrarostral groove; lower lip with a cluster of rictal papillae; no postoral pouch.

Description (data on holotype in paren-

theses).—Dorsal iii, 6–7 (iii,7) (only 1 of 14 with 6 branched rays); pectoral i,21–23 (i,21) (mean i,21.8; N = 21); pelvic i,14–15 (i,15) (mean i,14.8; N = 25); anal I,i,5 (I,i,5); lateral-line pores 55–63 (56) (mean 59.67; N = 18).

Total length 40–79 mm. (79); standard length 28.8–62.1 mm. (62.1); head width anterior to pectoral insertion 0.175–0.198 (0.183) (median 0.185; N = 15); gill opening 0.042–0.060 (0.045) (median 0.050; N = 14); eye 0.032–0.044 (0.032).

Head rounded; body fusiform, flattened below, becoming compressed behind origin of dorsal, dorsal profile rising in convex arc to dorsal origin, sloping downward to caudal; ventral profile straight.

Snout rounded; width of head just before insertion of pectorals 5.1–5.7 (5.5) in standard length; posterior margin of opercle slightly convex, with a wide opercular flap; usually skin wrinkled below cheek parallel to base of pectoral (Fig. 4E); anterior and posterior nostrils separated by valvular flap; anterior nostril more than twice as far from tip of snout as from eye; distance between pair of nostrils three-fourths interorbital; eye small, varying inversely with standard length, about 3 times in interorbital of 60 mm. fish; eye above level of gill opening; mouth ventral (Fig. 3D); a weak infrarostral groove; 4 rostral barbels originating before infrarostral groove; no prelabial pad; upper lip partly overhanging upper horny jaw; lower lip with a single row of widely spaced, simple papillae; a cluster of papillae at corner of mouth.

Pectoral horizontal, inserted below eye, posterior quarter of fin vertical; dorsal base of pectoral without scales; a broad ventrolateral flap between pectoral and pelvic fins, followed by a short, narrow suprapelvic adipose flap over anterior portion of that fin; length of suprapelvic flap subequal to diameter of eye, 0.026–0.047 of standard length (0.035) (median 0.032; N = 13); fused pelvics horizontal, posterior margin of fused fin truncate or notched; pelvics separated from anal by at least twice diameter of eye; origin of dorsal opposite beginning of pelvic, margin of fin straight; anal fin pointed, first branched rays longest, first two rays unbranched and much thicker than the remainder of fin, first ray spinous and 1½ times length of second; tip of adpressed anal reaching caudal or not so far; caudal fin truncate or slightly emarginate.

Lateral line curving downward between opercle and middle of body, horizontal in mid-lateral line thereafter; base of pectorals without scales; ventrolateral flap with small scales at its base, a broad scaleless margin; suprapelvic flap scaleless; ventral disk without scales.

Color in alcohol purplish brown; body with dark vertical bars irregular in shape and number; lower quarter of body behind pelvics yellowish; ventral disk yellowish; head without markings; dorsal fin membrane colorless; dorsal rays dusky, darker in middle portion; pectoral dusky above, pigment concentrated on rays; pelvic fins light dusky above, colorless below; anal fin colorless; caudal barred with black.

Mature males (50–55 mm.) have nuptial tubercles on the snout and on the dorsal surface of the pectoral fins. In addition they have numerous short, curved rows of sensory papillae on the entire side of the head from the level of the nostrils to the end of the opercle. Females with enlarged ova range from 51–62 mm. They may have a few small tubercles on the snout but lack the rows of sensory papillae.

Comparisons.—See above, p. 168–171.

Gastromyzon nieuwenhuisi (Popta)

Neogastromyzon nieuwenhuisi Popta, 1905, Notes Leyden Mus., 25:181—Howong River, Borneo.

Gastromyzon nieuwenhuisi Weber and de Beaufort, 1916; Fishes Indo-Austr. Arch., 3:4.

Material examined.—Sarawak (138).

Diagnosis.—A species of *Gastromyzon* with head with 5 times in standard length; edge of pelvic fin separated from anal fin by approximately twice eye diameter; rostral barbels originating anterior to infrarostral groove; lower lip usually without rictal papillae; a deep postoral pouch.

Descriptive notes.—Dorsal iii,6–8 (mean iii,7; N = 20); pectoral i,22–25 (mean i,23.3; N = 25); pelvic i,17–21 (mean i,18.7; N = 25); anal I,i,5; lateral-line pores 61–76 (mean 68.9; N = 20).

Total length 51–63 mm.; standard length 37.7–49.5 mm.; head width measured anterior to pectoral base 0.164–0.208 (median 0.190; N = 16); eye 0.035–0.047, becoming progressively smaller as standard length increases; gill opening 0.032–0.049 (median 0.039; N = 16); suprapelvic flap about 1½ times eye diameter, 0.055–0.093 of standard length (median 0.070; N = 16).

Fleshy base of pectoral without scales; ventrolateral flap without scales; suprapelvic flap scaleless; ventral disk without scales.

Color in alcohol purplish brown; body with

narrow light brown vertical bars; lower quarter of body behind pelvics yellowish; ventral disk yellowish without markings; head without markings; dorsal fin rays blackish, membrane colorless; pectoral fin rays dusky, darker in central thirds; pelvics similar to pectorals except darker near base; anal with faint dark bar across centers of rays; caudal with dark vertical black bars.

Mature males (37.7–43.4 mm.) have numerous nuptial tubercles on the snout and sides of head to the end of the opercle. The tubercles are not present on the pectoral fins. Rows of sensory papillae, such as those described for *pauciradiatus*, are absent. Females with enlarged ova measure 42.0–49.5 mm. They have no tubercles on the head.

Localities.—**Sarawak:** Third Division, tributary of Baleh River opposite Sungai Laie. **Indonesian Borneo:** Howong River (Weber and de Beaufort, 1916).

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Summary

The cyprinoid genus *Gastromyzon*, confined to Borneo, comprises five species, three (*punctulatus*, *fasciatus*, and *pauciradiatus*) described for the first time. These fishes live in clear, swift water and cling to rocks by means of a ventral disk formed by the flat ventral surface of head and abdomen, large horizontal pectoral fins, fused pelvic fins, and ventrolateral extensions of the body wall bridging the gaps between pectoral and pelvic fins. The gill openings are restricted to the sides and do not reach the bases of the pectoral fins. The mouths are ventral and have complex arrangements of barbels, grooves, and papillae showing specific differentiation.

The species differ in degree of specialization. Considering a long gill opening less specialized (since it more nearly resembles the generalized cyprinoid form) than a short one, *fasciatus* is the least and *nieuwenhuisi* the most specialized. In terms of number of fin rays, *fasciatus* is the most specialized and *pauciradiatus* the least.

The five species are sympatric in the Baleh River basin in central Sarawak.

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The Time and Order of Formation of Sensory Canals in the Fishes *Ophicephalus punctatus* (Ophicephalidae) and *Wallago attu* (Siluridae)

A. S. Kapoor

THE literature on the time and order of formation of sensory canals in the head of teleosts is scarce, and so far as the silurids are concerned, a systematic account on the subject does not exist. An account of the development of the cephalic sensory canals and related dermal bones in *Ophicephalus punctatus* Bloch and *Wallago attu* Bloch and

Schneider, and of the time and order of enclosure of the different neuromasts in the various canals of the head in these two fishes is given in the following pages.

The material for the study of *Ophicephalus punctatus* consisted of a complete set of larval stages measuring from 2.5 mm. (at the time of hatching) up to the adult stage, while that of *Wallago attu* consisted of specimens measuring from 9 to 33 mm. in length. In the following account, reference has been made only to those stages which show a definite advance over the preceding ones. All measurements correspond to the total length of the specimens after fixation. A preliminary examination of the different stages under a stereoscopic binocular microscope was followed by a study of serial transverse sections (cut from 6–24 micra thick, depending on the size of the individual specimens) of the cephalic region of all these stages. The material for the microscopical study was fixed in Zenker-Helly's and Bouin's fluids at room temperature for 12–16 hrs., and stained with Mallory's triple connective tissue stain, Mallory's phosphotungstic acid haematoxylin and Delafield's haematoxylin, counterstained with eosin.

Ophicephalus punctatus

The entire development of the various canals in this fish is abbreviated and several steps seem to overlap one another. The following account is an attempt to sum up the details as correctly as possible.

9.2 mm. stage: None of the neuromasts has been enclosed.

9.5 mm. stage: Only the fourth neuromast of the supraorbital line becomes enclosed in a small section of the canal.

9.8 mm. stage (Fig. 1A): The fifth neuromast (s.n.5) of the supraorbital line has also become enclosed in a section of the canal which has become continuous with that enclosing the fourth neuromast (s.n.4). Sections of the canal have also developed around the second neuromast of the infraorbital line (i.n.2), first four neuromasts of the preopercular line (pop.n.1–4) and the fourth and the third neuromasts of the mandibular line (ma.n.4 and 3).

10 mm. stage (Fig. 1B): The portion of the supraorbital canal enclosing the fourth and the fifth neuromasts has become continuous with that section of the canal which, in the meantime, has developed around the third neuromast (s.n.3). Small sections of the canal have appeared around the first and the third infraorbital neuromasts (i.n.1 and 3) and have become continuous with that enclosing the second (i.n.2). This whole forms the antorbital part (ant.or.) of the infraorbital canal. The seventh or the last neuromast of the infraorbital line (i.n.7) has been enclosed in a small section of the canal behind the eye. The temporal canal enclosing a neuromast (t.n.) has been formed and the preopercular canal now encloses the fifth and the sixth neuromasts (pop.n.5 and 6) as well; a small section of the canal has appeared around the second extrascapular neuromast (esc.n.2).

11 mm. stage (Fig. 1C): With the exception of the infraorbital (which is still incomplete), the rest of the canals have been fully formed

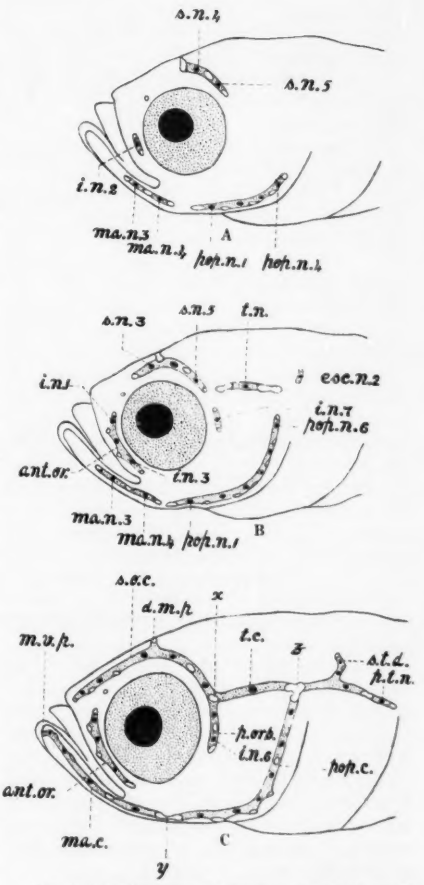

Fig. 1. Development of sensory canals in early stages of *Ophicephalus punctatus*: A. Stage at 9.8 mm. T. L.; B. Stage at 10.0 mm. T. L.; and C. Stage at 11.0 mm. T. L. See end of paper for abbreviations.

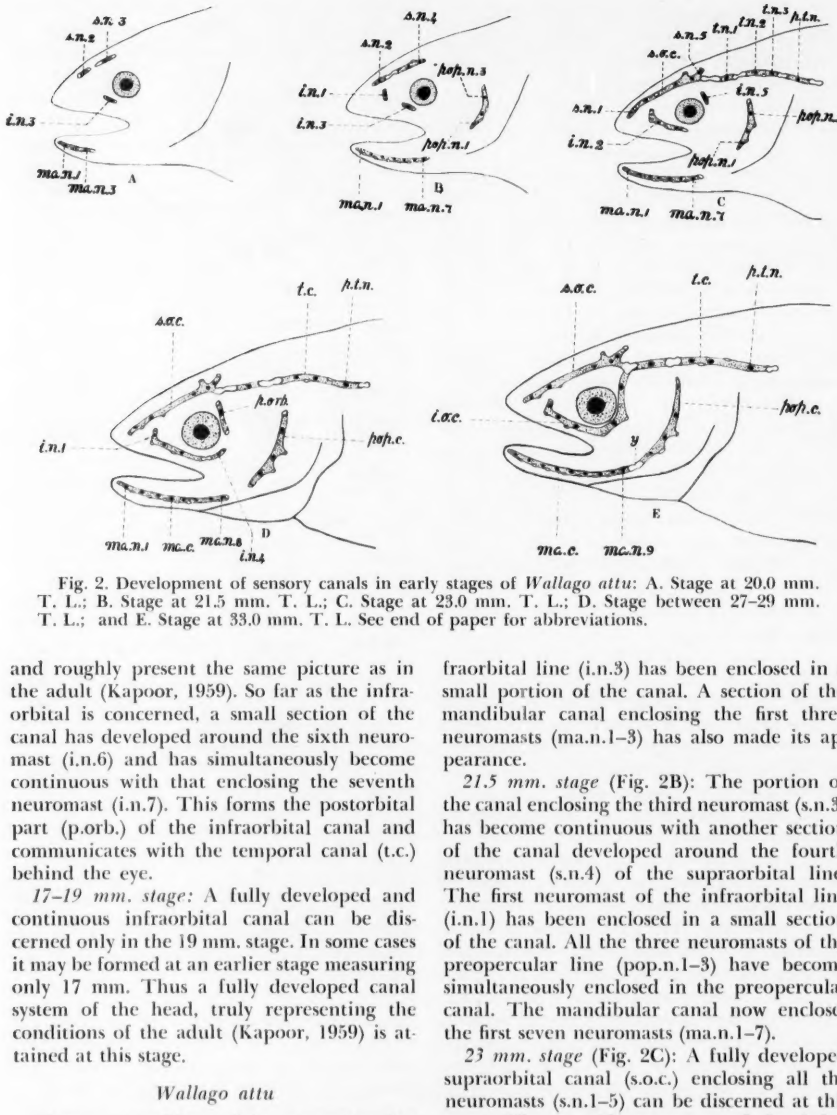

Fig. 2. Development of sensory canals in early stages of *Wallago attu*: A. Stage at 20.0 mm. T. L.; B. Stage at 21.5 mm. T. L.; C. Stage at 23.0 mm. T. L.; D. Stage between 27–29 mm. T. L.; and E. Stage at 33.0 mm. T. L. See end of paper for abbreviations.

and roughly present the same picture as in the adult (Kapoor, 1959). So far as the infraorbital is concerned, a small section of the canal has developed around the sixth neuromast (i.n.6) and has simultaneously become continuous with that enclosing the seventh neuromast (i.n.7). This forms the postorbital part (p.orb.) of the infraorbital canal and communicates with the temporal canal (t.c.) behind the eye.

17–19 mm. stage: A fully developed and continuous infraorbital canal can be discerned only in the 19 mm. stage. In some cases it may be formed at an earlier stage measuring only 17 mm. Thus a fully developed canal system of the head, truly representing the conditions of the adult (Kapoor, 1959) is attained at this stage.

Wallago attu

19 mm. stage: None of the neuromasts has been enclosed so far.

20 mm. stage (Fig. 2A): The enclosure of the mandibular, supra- and infraorbital canals starts simultaneously in the 20 mm. long stage. The second and the third neuromasts of the supraorbital line (s.n.2 and 3) are here enclosed in small and independent sections of the canal. The third neuromast of the infraorbital line (i.n.3) has been enclosed in a small portion of the canal. A section of the mandibular canal enclosing the first three neuromasts (ma.n.1–3) has also made its appearance.

21.5 mm. stage (Fig. 2B): The portion of the canal enclosing the third neuromast (s.n.3) has become continuous with another section of the canal developed around the fourth neuromast (s.n.4) of the supraorbital line. The first neuromast of the infraorbital line (i.n.1) has been enclosed in a small section of the canal. All the three neuromasts of the preopercular line (pop.n.1–3) have become simultaneously enclosed in the preopercular canal. The mandibular canal now encloses the first seven neuromasts (ma.n.1–7).

23 mm. stage (Fig. 2C): A fully developed supraorbital canal (s.o.c.) enclosing all the neuromasts (s.n.1–5) can be discerned at this stage. The second neuromast of the infraorbital line (i.n.2) has been enclosed in the canal, and now the portion of the infraorbital canal enclosing the first three neuromasts extends in front of, and below the eye. The fifth or the last neuromast of the infraorbital line (i.n.5) has become enclosed in a small section of the canal lying obliquely behind the hinder upper edge of the eye. The tem-

poral canal has appeared and it encloses all the three neuromasts (t.n.1–3).

27–29 mm. stage (Fig. 2D): A small portion of the canal has developed around the fourth neuromast of the infraorbital line (i.n.4) and has become continuous with that enclosing the first three neuromasts. This part of the canal is, however, still independent of the postorbital part (p.orb.) of the infraorbital canal enclosing the fifth neuromast. A mandibular canal (ma.c.) enclosing all the neuromasts, excepting the last one, has been formed.

33 mm. stage (Fig. 2E): All the sensory canals of the head have been fully formed, truly representing the condition in the adult (Kapoor, in press). The preopercular canal is still independent of the temporal canal because that section of the canal which is enclosed by the suprapreopercular bone in the adult, has not been developed so far.

Adult stage: The preopercular canal has extended dorsally, and it now communicates with the temporal canal. The sensory canal system of the head in the adult fish has been described by Kapoor (in press).

Discussion

A previous systematic account of the time and order of formation of the sensory canals in any silurid is lacking. Pollard's (1892) account of certain larval forms does not provide pertinent information in this respect. Thus in a 3 cm. long specimen of *Callichthys*, he describes a short preopercular canal independent of the temporal canal. A mandibular canal is stated to be absent, while the rest of the canals have been fully formed. In a 2.5 cm. long specimen of *Trichomycterus*, he describes the infraorbital canal as consisting of a short anterior portion in front of the eye, and a postorbital portion continuous with the supraorbital canal. Likewise, in *Ameiurus*, Allis (1904) states that the ". . . superior postorbital organ becomes first enclosed in a section of canal that encloses also the one otic organ of the horizontal part of the canal." In the infraorbital canal of *Wallago* the third neuromast is the first to become enclosed in the canal (20 mm. stage). Moreover, contrary to the condition in *Ameiurus*, the 23 mm. stage of *Wallago* shows an anterior section of the infraorbital canal enclosing the first three neuromasts in addition to a posterior portion enclosing the fifth neuromast, the latter section being quite independent of the temporal canal. A connection between the temporal canal and the infraorbital canal in *Wallago* is established only when the fish has attained a length of 33 mm. In *Trichomycterus* Pollard (1892) describes a fully developed temporal canal and the "operculo-mandibular canal" is stated to be absent. The supraorbital canal is described as consisting of a short anterior and a longer posterior part. The same is true for *Ameiurus* (Allis, 1904), and as I have stated in *Wallago* also, this canal starts its development in two sections (20 mm. stage), which become continuous with each other in the 23 mm. stage.

In *Wallago*, the sensory canals of the head attain a complete development when the fish has reached a length of 33 mm., but the preopercular canal still remains independent of the temporal canal. In a 25 mm. long specimen of *Heteropneustes fossilis* Bloch, which I had the opportunity to examine, all the canals (with the exception of a discontinuous infraorbital) were fully formed. According to Bamford (1941), in *Clupea harengus*, they are formed when the fish attains a length of 50 mm. Lekander (1949) states that "In *Phoxinus* the canal formation is finished when the fish is sexually mature, in *Nemachilus* at a length of 47 mm., in *Alburnus* at 42 mm. etc.". In *Esox* (Pehrson, 1944a), the canals are not fully developed even up to the 40 mm. long stage.

Judging from the above, it is obvious that the canals are formed at a comparatively earlier stage in the silurids as contrasted with the fishes enumerated above. But in *Ophicephalus punctatus* they form extremely early, and the conditions in this fish provide further evidence to Lekander's generalization that in the Acanthopterygii, the canals "seem practically always, to form early as compared to other fishes." Thus in this fish, all the canals (with the exception of the infraorbital) are fully formed by the time it reaches a length of 11 mm. A fully formed infraorbital canal is, however, discernible only when the fish has reached a length of 17–19 mm.

Allis (1889) states that in *Amia* the canals, on the whole, are enclosed much earlier at the anterior end of the head than those behind the eye. According to Pehrson (1944b), in *Acipenser*, the posterior portion of the dorsal part of the canal system develops at an earlier stage than the anterior. In *Batrachus* (Clapp, 1898), the most anterior organs are the first to become enclosed, but in the cyprinids (Lekander, 1949), as a rule, "the anterior part of the preopercular canal develops first, then the anterior part of the frontal canal. In *Phoxinus*, however, the mandibular canal

forms first, then the preopercular canal." In *Nemachilus* (Lekander, 1949), on the other hand, the infraorbital and the temporal canals form much earlier than the remaining canals. In *Ophicephalus punctatus*, as already described by me, the fourth neuromast of the supraorbital line is the first to become enclosed (9.5 mm. stage); this is followed by the enclosure of the fifth neuromast of the supraorbital line, and the posterior, anterior and ventral sections of the mandibular, infraorbital and preopercular canals, respectively (9.8 mm. stage). In *Wallago*, the second and the third neuromasts of the supraorbital line, the third neuromast of the infraorbital line and the first three neuromasts of the mandibular line are the first to become enclosed (20 mm. stage). In *Amia* and in other teleosts, the mandibular canal usually forms from front backward, but in *Ophicephalus punctatus* the order is entirely reversed, the canal, here, developing from behind forward.

In most cases, as Allis (1889) states for *Amia*, the canals are formed much earlier at the anterior end of the head in comparison to those behind the eye, but the fore-going account would show that this can not be accepted as a rule for all bony fishes. The factors responsible for this diversity in the order of enclosure of the canals in different fishes are not known. The canals may form in roughly the same order within a specific group, but even this is true within reasonable limits. A glance at the data collected by Lekander (1949), supplemented by my own observations on *Wallago attu* and *Ophicephalus punctatus*, shows that conditions differ in different species in this particular respect. Obviously, therefore, any attempt to draw definite conclusions in this respect for the teleosts in general is insecure, and Lekander's hypothesis that the canals in these fishes form in a certain order is, in the opinion of the present author, untenable. Nevertheless, there are certain features about the development of the canals which remain constant in the teleosts, as for example:

(1) The supraorbital canal develops in two parts (belonging to the nasal and the frontal bones) which become continuous with each other at a later stage.

(2) The infraorbital canal is invariably the last to be formed. It develops in three parts—one in front, another behind and the third below the eye. The first two of these appear considerably earlier than the third.

(3) The mandibular and preopercular canals always develop independently, and become connected with one another at a later stage. The ventral portion of the preopercular canal is formed first, while the dorsal portion appears considerably later.

Summary

(1) The time and order of formation of the various sensory canals of the head in *Ophicephalus punctatus* and *Wallago attu* has been recorded, and a comparison of the same with the available descriptions of certain other fishes has been made.

(2) In *Wallago*, the canals complete their development at the 33 mm. stage but the preopercular canal attains a communication with the temporal canal at a still later stage. In the silurids in general, the canals are formed earlier as compared to *Esox*, *Clupea*, certain cyprinids and cobitids.

(3) In *Ophicephalus*, they are fully formed in the 19 mm. long stage, or even earlier i.e., in the 17 mm. stage. The extremely early appearance of these canals in this fish goes in support of Lekander's view that in the Acanthopterygii in general, they appear early as compared to other fishes.

(4) There is a great diversity in different fishes concerning the order of enclosure of the neuromasts in the various canals and, therefore, any generalization in this respect for the teleosts is, in the opinion of the present author, neither feasible nor desirable.

(5) In both the examined fishes the supraorbital canal develops in two parts which become continuous with each other at a later stage.

(6) The infraorbital canal is the last to develop. It appears in three parts—one in front, another behind and the third below the eye. The first two of these appear considerably earlier than the third.

(7) The mandibular and the preopercular canals develop independently and become connected with one another at a later stage. The ventral portion of the preopercular canal forms earlier than the dorsal part.

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Explanation of Lettering in Figs. 1 and 2

ant.or.—antorbital part of the infraorbital canal.
d.m.p.—dorso-median pore.
esc.n.—neuromast belonging to the extrascapular bone.
i.n.—neuromast of the infraorbital canal.
i.o.c.—infraorbital canal.
ma.c.—mandibular canal.
ma.n.—neuromast of the mandibular canal.
m.v.p.—median ventral pore.
p.orb.—postorbital part of the infraorbital canal.
pop.c.—preopercular canal.
pop.n.—neuromast of the preopercular canal.
p.t.n.—neuromast belonging to the posttemporal bone.
s.n.—neuromast of the supraorbital canal.
s.o.c.—supraorbital canal.
s.t.d.—supratemporal diverticulum.
t.c.—temporal canal.
t.n.—neuromast of the temporal canal.
x—pore at the junction of the supra- and infraorbital canals.
y—pore at the junction of the mandibular and preopercular canals.
z—pore at the junction of the preopercular and temporal canals.

Department of Zoology, Meerut College, Meerut, India.

Hybridization Versus Integradation: An Inquiry into the Relationship of Two Cyprinid Fishes

Carter R. Gilbert

According to Mayr, Linsley and Usinger (1953:25, 30), "Species are groups of actually (or potentially) interbreeding natural populations which are reproductively isolated from other such groups;" subspecies are defined as "... geographically defined aggregates of local populations which differ taxonomically from other such subdivisions of a species." It has become evident in recent years that the above taxonomic categories are not as clear-cut and precise as these definitions imply. Systematic researches on various groups of North American freshwater fishes, particularly the minnows (family Cyprinidae), have contributed importantly to this reappraisal. In some instances it is extremely difficult, if not impossible, to determine objectively in which of the above categories certain forms should be placed.

The cyprinid genus *Notropis*, because of its recent origin, large size, and continued evolution, furnishes numerous examples of incipient species and of species that are near the subspecific level in their degree of evolution. One of the most readily demonstrable cases involves *Notropis cornutus* (including populations formerly regarded as a distinct subspecies, *frontalis*, but herein considered a synonym of *cornutus*) and *Notropis chrysocephalus chrysocephalus*, two species that exhibit an extremely interesting and complex relationship, and which, until now, have been regarded as subspecies. A detailed discussion of this relationship, including evidence for the above taxonomic interpretation, is presented in this paper, together with a discussion of hybridization and intergradation, as it applies to the species-subspecies problem, with pertinent examples involving other North American freshwater fishes and the amphibian, *Rana pipiens*.

Hybridization and Intergradation

When two genetically dissimilar animals (that is, those which have differentiated at least to the subspecific level) mate, the resultant offspring may be classified either as hybrids or as subspecific intergrades, depending on the criteria which are analyzed in Table 1.

The concept of hybrid intermediacy is based on empirical findings and the currently favored explanation for the morphological data depends on the combined quantitative effects of multiple genes. The identification of naturally produced hybrids rests almost entirely upon structural intermediacy (e.g., Hubbs and Kuronuma, 1942:301–02; Hubbs, 1955:4–5; Trautman, 1948:167–70; and 1957: 113–6). Generally speaking, this is an extremely valuable tool, but there are exceptions and limitations. Sometimes interspecific crosses are not exactly intermediate between their presumed parents, a fact which on occasion has led to confusion in making determinations (Hubbs and Bailey, 1952:143–52; Bailey and Gilbert, 1960). Characters may be identical to, or closely approach, the phenotype of one parent, or they may be outside the range of either parent (Hubbs and Strawn, 1957:6–7). In cases where characters may be controlled by one or a few genes in which dominance and recessiveness are involved, there may be a summation of the combined gene effects, or there may be some other complicated gene interrelationships. The genetic

Table 1. Summary of Criteria Used in the Determination of Interspecific Hybrids and Intersubspecific Intergrades

Criterion	Hybrids	Intergrades
Appearance of offspring	Usually intermediate	Of average intermediacy; characteristically forming a graded series between parental forms
Ratio of number of phenotypic intermediates to parents within a population	Typically low, forming "U-shaped" curve when graphed	High, intergrades out-numbering parental phenotypes, forming a "bell-shaped" curve when graphed
Frequency of hybrids or intergrades among populations containing both parental forms	Not 100%; varies according to parental forms involved and to ecological conditions	100%
Degree of fertility	Often partially or completely sterile in at least one sex	Both sexes completely fertile
Sex ratio	Often abnormal	Normal; i.e., typical of parental stock
Heterotic effects	Often present	Absent
Phylogenetic relationship of parents	Often not close	Very close
Ecological preferences of parents	Usually different	Usually similar or very close
Breeding behavior of parents	Usually different	Usually similar
Physiological characteristics of parents	Usually different	Usually similar or identical
Geographic occurrence	Usually widespread but local	Usually limited to more or less definite geographical areas

control of morphological characters is more complicated than was once supposed.

Examples in North American Freshwater Fishes

Many examples of hybridization are known in North American freshwater fishes. In most cases there is no question of the relationships of the species involved. The offspring of crosses which commonly occur in the sunfishes (family Centrarchidae), particularly in the genus *Leptomis,* show all the hybrid characteristics listed in Table 1. Naturally occurring centrarchid hybrids usually result from heterogametic matings, and are most apt to occur in situations where there is a shortage of good spawning habitat (Bailey and Lagler, 1938:605; Hubbs, 1955:18).

The hybrids, *Notropis cornutus* × *Notropis rubellus* and *Notropis chrysocephalus* × *Notropis rubellus,* are among the most common cyprinid crosses in eastern United States. They occur as a consequence of the simultaneous spawning of the two parents, which may occur over nests of species of the subgenus *Nocomis* (genus *Hybopsis*) or other nest building cyprinids, or over a rubble bottom in different parts of the same riffle (Hubbs and Brown, 1929:36–7; Raney, 1940:363–4; Hubbs, 1955:10). An examination of 18 subadult to adult specimens of the *cornutus* × *rubellus* combination taken during the months of May and June in western New York showed on equal ratio of males to females (Raney, 1940: 364). There is no direct proof that the hybrids of this cross are fertile, although both sexes are capable of producing sex elements. The hybrids may spawn with one another, although this has not yet been observed. Both sexes may spawn in nature with *cornutus,* and the finding that some hybrids appear to be structurally closer to one parent suggests that backcrossing may occur (Raney, 1940: 362). Hubbs and Brown (1929:36), in describing the hybrid between *cornutus* and *rubellus,* reported, "our large number of specimens from numerous localities completely bridge the wide gap in characters between the two parent species." This suggests that the breeding act involving a hybrid and one or both parent species may be successful.

The cyprinids, *Chrosomus eos* and *Chrosomus neogaeus,* two well-defined species which occur sympatrically over a wide area of southern Canada and northern United States, are known to hybridize in many areas (Greeley and Bishop, 1932:84; and 1933:96; Greeley, 1934:102; Taylor, 1954:42). Numerous collections show that in some localities little or no hybridization occurs, whereas in other places populations consist largely of hybrid individuals.

Notropis lutrensis and *Notropis venustus* occur sympatrically only in relatively small, though widely separated, parts of their ranges. They prefer somewhat different ecological conditions, with *lutrensis* favoring quieter and more turbid waters than does *venustus.* In most localities where the two forms live sympatrically, little or no hybridization is known to occur. Occasionally, however, hybrid swarms are found which show a complete gradation from one parental species to the other. Studies by Hubbs and Strawn (1956:341–4) in Texas indicate that hybridization occurs only under conditions of environmental disturbance. This is admirably demonstrated in the Guadalupe River (Hubbs, Kuehne, and Ball, 1953:226, 230). *N. lutrensis* and *N. venustus* occur together throughout a large part of this basin, with both species being particularly abundant in the upper regions. In headwater tributaries, where ecological conditions remain relatively unchanged, there is little or no hybridization, whereas in areas where a sudden increase in turbidity of the water has occurred, hybrid swarms are found. Hybrids apparently first made their appearance in the Guadalupe system in the 1930's, at the same time that a gravel company started to dump its wash into the river, a policy that has continued to the present. The remarkable relationships that occur here rather convincingly demonstrate that hybridization has occurred as a result of man's influence.

Laboratory investigations on specimens from the Guadalupe have shown that artificially reared hybrids between *N. lutrensis* and *N. venustus* are vigorous and apparently completely fertile. Not only have both sexes of the F_1 individuals been backcrossed successfully with the parents, but they also have been mated with each other to produce F_2 hybrids. It is logical to assume that a pure inbred strain of this nature would be unable to maintain itself indefinitely, a point that only experimentation can settle. There appears to be no genetic barrier to interbreeding between these two species, at least among the members of the population studied. Hubbs and Strawn (1956:343–4) say in summary, "Repeated simultaneous captures of young of both species indicate no seasonal reproductive isolation. Although the two species tend to

occupy different macro- and microhabitats, *N. venustus* in swifter water than *N. lutrensis*, there is approximately 25 percent overlap in wild-caught samples.... either mate recognition or breeding site selection is suspected as the major isolating factor in those regions where the two species do not interbreed. In the few areas where hybrid swarms occur, disturbances of the environment may well have broken these barriers between the species."

According to Trautman (1957:115, 287–8), "There is considerable circumstantial and factual evidence to indicate that in Lake Erie the hybrids of *Cyprinus carpio* and *Carassius auratus* are almost or entirely as fertile as are the parent species; in some areas the hybrids actually may outnumber either one of the parents." Experimental evidence indicates that only the females of this cross are fertile (Matsui, Makino, and Ojima, 1956: 52–60). In spite of the extensive hybridization in Lake Erie, natural hybrids between these two species apparently are rare elsewhere, although they occur sympatrically in a number of places. It is not known whether this phenomenon is due to the genetic constitution of the carp-goldfish population in Lake Erie, or is a product of the shallow, warm, turbid waters typical of the western parts of this lake.

There are some who might contend that the relationships of *Chrosomus eos* to *Chrosomus neogaeus*, *Notropis lutrensis* to *Notropis venustus*, and *Carassius auratus* to *Cyprinus carpio* are at the subspecific level. If so, how would one treat the populations of these forms that live sympatrically and fail to hybridize? Even though *N. lutrensis* and *N. venustus* may interbreed freely, this is an unusual situation and occurs only under conditions of environmental disturbance; the exact causes of hybridization between the other species are unknown at the present time. Although F_1 hybrids of these three crosses are apparently fertile, this in itself does not necessarily prove a subspecific relationship. Many hybrid fish combinations produced artificially in the laboratory yield fertile offspring (Tavolga, 1949:222–3).

The situation in the frog, *Rana pipiens*, is of considerable importance in arriving at an understanding of the present problem. Moore (1949:315–38) found complete fertility between individuals from neighboring populations. With some exceptions, the degree of fertility between populations decreases in direct proportion to geographical distance, so that there is almost 100 percent mortality in the gastrula and morula stages of crosses from Mexico and New England. Although the more distant populations act as physiologically distinct species, adjacent stocks fail to approach even the subspecific level of differentiation. Since there is no apparent "break" in this gradient, it seems unlikely that this species can be divided into taxonomic segments.

The relationship of *Notropis cornutus* and *Notropis chrysocephalus chrysocephalus* is one of the most interesting and complex among North American freshwater fishes. These species occupy large areas in eastern United States, and are allopatric throughout most of their ranges (Figs. 4 and 5). They occur sympatrically in the southern Great Lakes drainage from southeastern Wisconsin eastward to west-central New York, and in a number of headwater areas of the Mississippi and Ohio River drainages, a distributional pattern which indicates that, following the Wisconsin glaciation, *N. chrysocephalus* invaded the Great Lakes via the Chicago and Maumee glacial outlets (Radforth, 1944:103). Within this area of sympatric occurrence all degrees of relationship seem to exist (Table 2 and Fig. 6). Some populations consist of only one form; in other places the two apparently exhibit a subspecific relationship, with populations containing many more or less intermediate individuals; or the two forms may exhibit a specific relationship, in which case individuals can be separated readily, often with a predominance of one kind and with few or no intermediate individuals.

The above relationship is in contrast to the situation in *Fundulus diaphanus*, in which repopulation of the Lake Ontario basin by two stocks of this species following the glacial recession was attended by complete genetic amalgamation. These structurally distinctive forms had not differentiated physiologically to the species level (Hubbs and Lagler, 1958: 97).

Notropis cornutus and *Notropis chrysocephalus chrysocephalus* are most readily distinguished by the relative size and arrangement of the predorsal and anterior dorsolateral scales, these scales being small and unevenly situated in the former species, and larger and more evenly arranged in the latter form. In order to express this difference in scale size, two kinds of counts are used, the circumferential and anterior dorso-lateral, and these are summed for each species in the final tabulation. The former is made by counting those scales around the circumference of the body, in a linear series just

TABLE 2. COMPARISON OF SELECTED MIXED POPULATIONS OF *Notropis cornutus* AND *Notropis chrysocephalus chrysocephalus*[1]

Catalogue no. [2] and locality	Sum of anterior dorso-lateral and circumferential scale counts																							No.
	under 40	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	over 59		
Illinois																								
INHS, N. Nippersink Cr., McHenry Co.	—	—	1	2	3	1	1	—	—	—	2	—	3	1	4	9	3	4	5	2	2	—		44
Indiana																								
163126, Pigeon R., LaGrange Co.	—	3	11	7	7	6	1	1	1	4	—	2	—	1	1	—	2	—	—	1	—	—		48
IU 16, Little Elkhart R., Elkhart Co.	—	—	3	6	7	4	2	3	2	2	—	1	—	2	3	3	6	8	5	1	1	1		60
IU 33, St. Joseph R., Elkhart Co.	—	—	1	5	6	17	10	11	4	1	—	—	—	—	—	—	—	—	—	1	—	—		56
IU 38, Turkey Cr., Elkhart Co.	—	—	—	1	4	3	—	—	—	—	2	1	3	1	6	8	2	2	2	2	—	—		37
IU 122, Pine Cr., Marshall Co.	1	2	4	9	11	3	5	1	1	—	1	—	—	—	—	—	—	—	1	—	—	—		40
IU 145, Sugar Cr., Whitley Co.	—	—	1	—	1	2	—	—	1	—	3	1	2	1	2	—	1	2	4	1	—	—		22
IU 147, Eel R., Whitley Co.	—	—	—	—	—	—	—	1	—	—	—	—	1	1	2	1	2	1	2	1	—	—		12
IU 148, Cedar Cr., Allen Co.	—	—	—	1	—	2	—	3	1	1	—	1	1	4	3	6	8	2	6	6	2	3		50
New York																								
98817, Murder Cr., Akron, Erie Co.	—	—	—	—	8	5	2	7	6	5	3	3	2	3	2	1	1	—	—	1	—	1		50
98990, Delaware Cr., Erie Co.	—	—	2	3	1	1	1	1	1	—	—	—	—	—	1	—	1	1	—	—	—	—		13
98993, Little Sister Cr., Erie Co.	—	1	1	5	2	2	1	2	—	—	1	2	—	2	4	1	1	2	2	—	—	1		30
Ohio																								
118537, Ten Mile Cr., Lucas Co.	—	—	3	5	2	—	—	—	—	—	—	—	—	1	1	1	—	2	—	—	—	—		15
OSU 9142, Possum Cr., Richland Co.	—	—	—	—	—	—	1	—	—	3	4	4	8	10	12	6	3	3	—	—	—	—		54
OSU 4/181, Orange Cr., Ashland Co.	1	4	14	16	17	11	10	4	2	3	3	—	—	1	1	1	2	2	2	1	—	—		95
OSU 4/184, Newell Run, Ashland Co.	1	1	3	11	14	8	3	3	2	4	2	4	10	8	8	8	5	2	1	1	1	—		100
Pennsylvania																								
99667, Big Mahoning Cr., Indiana Co.	3	1	6	4	1	2	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—		18
99668, Ross Run, Indiana Co.	—	—	4	1	1	1	—	—	—	—	1	3	2	1	1	2	—	1	1	—	—	—		19
99676, Pickering Cr., Indiana Co.	3	5	5	5	4	2	5	1	—	2	4	1	2	2	2	—	2	1	1	2	1	—		50
110722, Newcastle, Lawrence Co.	1	2	5	6	4	2	3	1	2	—	—	1	1	—	—	—	—	—	—	—	—	—		28
Michigan																								
66270, Sucker Cr., Shiawassee Co.	—	1	2	11	11	12	5	5	—	—	2	1	2	2	1	2	2	3	—	—	—	—		62
89573, Clear Springs Cr., Lenawee Co.	—	—	2	1	3	7	2	3	1	—	—	—	—	—	—	—	1	—	—	—	—	—		20
89914, River Raisin, Lenawee Co.	—	2	1	1	5	6	7	7	2	4	2	—	—	—	1	2	3	—	2	—	—	—		45
101910, Hog Cr., Branch Co.	—	—	—	6	5	6	3	1	1	3	4	1	3	1	1	4	7	8	4	2	2	1		63
102065, Tiffin R., Lenawee Co.	—	—	1	10	6	8	3	—	3	4	4	1	2	3	6	4	6	5	2	4	—	2		75
106958, Utica, Macomb Co.	—	—	—	2	6	4	5	6	4	2	8	8	10	27	43	57	82	67	50	29	20	10		441
106982, Utica, Macomb Co.	—	—	—	1	—	—	—	2	—	—	—	1	1	1	2	3	7	5	—	2	2	3		30
164320, Kalamazoo R., Calhoun Co.	—	—	2	3	4	3	4	6	—	—	2	2	4	3	13	16	18	20	14	4	3	5		127
164330, Kalamazoo R., Calhoun Co.	—	1	3	10	6	14	10	7	5	2	—	5	2	7	3	11	6	11	5	2	1	1		114
164338, Kalamazoo R., Jackson Co.	1	1	2	2	10	4	3	3	3	2	—	3	—	4	1	4	1	4	5	4	1	1		59
164345, Kalamazoo R., Jackson Co.	—	2	6	9	16	13	9	5	8	9	6	5	9	8	8	3	4	3	1	1	—	—		125
164363, Kalamazoo R., Jackson Co.	5	3	11	36	33	21	13	3	7	4	2	2	2	3	3	3	3	—	3	—	2	—		159
Wisconsin																								
64587, Milwaukee R., Washington Co.	—	1	3	3	2	4	1	—	—	—	—	—	2	1	—	—	—	1	—	1	—	—		19
Ontario																								
85526, AuSable R., Middlesex Co.	—	1	2	7	6	4	2	1	1	1	2	2	5	10	12	14	9	7	6	3	3	2		100
85597, Grand R., Breslau Co.	—	2	9	14	16	5	3	3	1	—	—	—	—	—	3	2	—	2	—	—	—	—		60
89006, trib. of Thames R., Kent Co.	1	8	12	11	13	7	2	1	—	—	—	2	4	4	6	10	9	4	2	2	1	—		99
89093, Cedar R., trib. of Grand R.	1	—	1	—	3	—	—	1	—	3	5	11	7	7	9	14	18	8	8	6	3	—		105

[1] Counts for additional mixed populations may be found in Gilbert (1960).
[2] INHS (Illinois Natural History Survey); IU (Indiana University); OSU (Ohio State University). All other numbers indicate collections in the Museum of Zoology, University of Michigan (UMMZ).

anterior to the dorsal fin, beginning with the first scale above the lateral line and ending with the lateral line scale. The anterior dorso-lateral count is made along the longitudinal row of scales lying approximately three-fourths of the distance from the lateral line to the middorsal line. This is the third to sixth row above the lateral line, depending upon the size of the scales. Commencing at a point directly under the origin of the dorsal fin, the scales are counted forward to their termination. An analysis of these counts shows that, of 2546 specimens of *Notropis cornutus* counted from various parts of its range, 90 percent had values of from 48 to 59, with the extremes 42 to 67; in 1023 specimens of

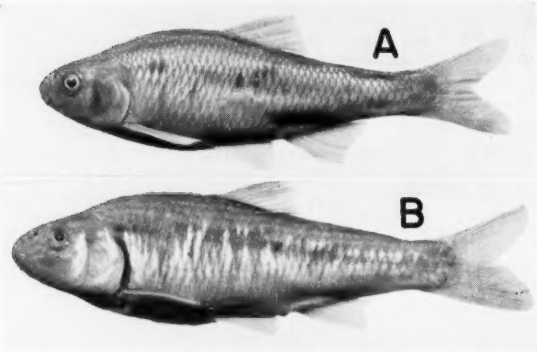

Fig. 1. A. *Notropis cornutus*. Adult male, 106 mm. in standard length, from the Maumee River system, Ohio (UMMZ 121835). B. *Notropis chrysocephalus chrysocephalus*. Adult male, 140 mm. in standard length, from the Cumberland River system, Kentucky (UMMZ 154507). Note differences in pigmentation pattern and size of scales on anterior dorso-lateral part of back.

Notropis chrysocephalus chrysocephalus, 90 percent of the counts were from 40 to 44, and the extremes 38 to 48.

In addition to differences in scale counts, these species show different color patterns along the sides of the back, characters that are most evident in breeding males. *Notropis cornutus* possesses a wide, light olive stripe, running along the length of the back just below the predorsal stripe (Figs. 1 and 2). In life, the latter marking, as well as a narrow streak situated below the wide, olive stripe, assumes a gilt coloration, which disappears very soon after death. In contrast, *Notropis chrysocephalus chrysocephalus* has a series of zig-zag stripes, usually three in number, running along the anterior dorso-lateral part of the back, and does not possess either of the other characters listed above for *N. cornutus* (Figs. 1 and 2). Also, *chrysocephalus* usually has pigment on the chin and anterior gular region on the underside of the head, whereas this is ordinarily lacking in *cornutus* (Fig. 3). Although the latter character does not hold true for all specimens, and breaks down in certain parts of the respective ranges of these species, it seems to be rather consistent in the area of sympatric occurrence.

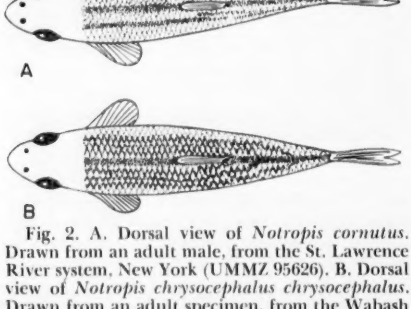

Fig. 2. A. Dorsal view of *Notropis cornutus*. Drawn from an adult male, from the St. Lawrence River system, New York (UMMZ 95626). B. Dorsal view of *Notropis chrysocephalus chrysocephalus*. Drawn from an adult specimen, from the Wabash River System, Indiana (UMMZ 100877). Note difference in pigmentation pattern along sides of back.

Counts involving the sum of the anterior dorso-lateral and circumferential scales in mixed populations of *N. cornutus* and *N. chrysocephalus chrysocephalus* are listed in Table 2 [see footnote in table for explanation of abbreviations below]. The frequency of counts varies from population to population, an indication of the varied interrelationships existing between these two species. For example, a series from Murder Creek, near Akron, New York (UMMZ 98817), seems to consist primarily of intermediate individuals; other series are composed almost entirely of *N. cornutus* (Eel River, Whitley Co., Indiana [IU 147]; Wolf Creek, Lenawee Co., Michigan [UMMZ 87901]) or of *N. chrysocephalus* (Pine Creek, Marshall Co., Indiana [IU 122]; Newcastle, Lawrence Co., Pennsylvania [UMMZ 110722]); in other cases both forms are common and the taxonomic separation seems to be virtually complete (AuSable River, Middlesex Co., Ontario [UMMZ 85526]; tributary of Thames River, Kent Co., Ontario [UMMZ 89006]). Although segregation of these forms by means of scale counts is usually substantiated by a gross examination of specimens, this is not always true. A case in point is the col-

lection from Sucker Creek, Shiawassee County, Michigan (UMMZ 66270). According to the distribution of counts, less than 10 percent of the specimens in this series qualify as hybrids. Nevertheless, the overall impression of the population is one of intermediacy, particularly with regard to the more coarsely-scaled individuals. This suggests a number of possible interpretations: scale counts of F_1 hybrids are not exactly intermediate between the parents (this may be a reflection of the reliability of counting methods); extensive backcrossing has taken place; or, the parallel stripes along the length of the back, which are the main criteria by which *chrysocephalus* may be distinguished from large-scaled hybrids, are indistinct or absent in some populations (as happens occasionally in series of valid *chrysocephalus* from more southern parts of its range). It is possible that any or all of the above are involved.

The presence of apparent intergrading populations of *Notropis cornutus* and *Notropis chrysocephalus chrysocephalus*, together with their seemingly identical spawning habits (Hankinson, 1932:415–7, 423), constitute the chief arguments for the recognition of these forms as subspecies. In addition, the production of sex elements by phenotypically intermediate adults, indicating at least limited fertility in the F_1 generation, also suggests differentiation at the subspecific level. While identical spawning habits ordinarily are indicative of a close genetic relationship (that is, below the specific level), this is not necessarily always true. For example, in *Notropis spilopterus* and *Notropis whipplei*, two closely related but morphologically distinct species living sympatrically over a large area of eastern United States, there appears to be no detectable difference in spawning behavior (Trautman, 1957:371). With regard to hybrid fertility, it should be noted that hybrids of *N. cornutus* × *N. rubellus* (and, presumably, *N. chrysocephalus chrysocephalus* × *N. rubellus*) are often partially or entirely fertile (Raney, 1940:366), even though the parents are not intimately related, and, in addition, hybrids involving *N. lutrensis* and *N. venustus* (Hubbs and Strawn, 1956) also exhibit a high degree of fertility. There is a great deal of evidence, in addition to that of morphological distinctness in sympatric populations, to indicate that *N. cornutus* and *N. chrysocephalus* have differentiated to the species level. This evidence is discussed below.

The rather complete separation of *N. cornutus* and *N. chrysocephalus* on the basis of scale counts in many areas where they occur sympatrically is further substantiated by the presence or absence of pigmentation on the chin and anterior gular areas (Fig. 3). Many collections containing both forms can be accurately separated by means of this character alone. It seems likely that, should *cornutus* and *chrysocephalus* show complete genetic

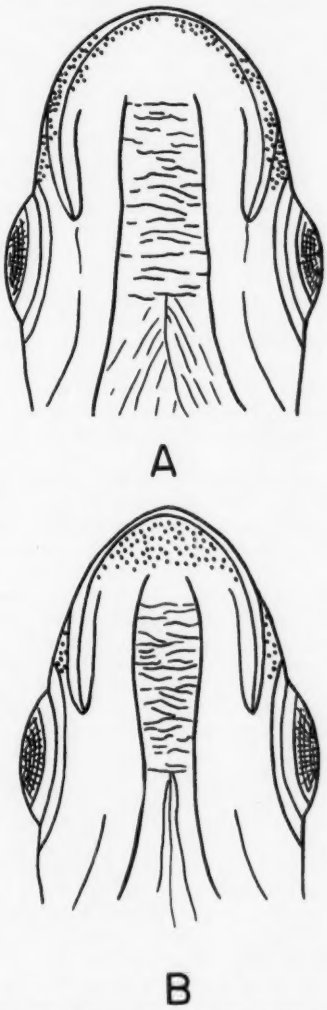

Fig. 3. A. Ventral view of head of *Notropis cornutus*, showing near absence of pigment on chin and anterior gular area. B. Ventral view of head of *Notropis chrysocephalus chrysocephalus*, showing presence of pigment on chin and anterior gular area.

amalgamation throughout the region of mutual occurrence (that is, show a typical subspecific relationship), chin pigmentation would show an average intermediacy in all mixed populations.

Distinct physiological differences are found between *cornutus* and *chrysocephalus*. The former apparently is able to tolerate a colder mean temperature and/or is capable of breeding at a lower minimum temperature. The northern limit of distribution for *cornutus* corresponds rather closely to the 65°F. July isotherm, whereas that for *chrysocephalus* corresponds to the 70°F. July isotherm (Radforth, 1944:88–9). Observations of these two fishes in southern Michigan give little indication of significant differences in time of spawning; both forms apparently ripen simultaneously in this area, and both seem to remain in spawning condition for the same length of time. It is possible that a more exhaustive study might reveal significant differences in the time and duration of ripening. Investigations by Hart (1952:18–21) on maximum temperature tolerances of these two forms show that *N. cornutus* from the vicinity of Toronto, Ontario, died at a significantly lower temperature than did *chrysocephalus* from Knoxville, Tennessee, a phenomenon that suggests genetic differences between these species. It would be desirable to repeat these experiments using specimens of *cornutus* and *chrysocephalus* from the same geographic area.

Where *N. cornutus* and *N. chrysocephalus chrysocephalus* are sympatric, the former tends to occupy headwater areas, while the latter usually lives toward the stream mouths. Thus, a preference by *cornutus* is indicated for the cooler, swifter waters and by *chrysocephalus* for the warmer, slower waters. This is shown by the relative distributions of these species in Michigan (Fig. 6), a comparison that becomes quite striking when one considers that those collections containing a single form were plotted only when ten or more specimens were present, whereas all collections containing both *cornutus* and *chrysocephalus* were plotted, regardless of number. This has resulted in emphasis being placed on stray individuals of one species which may occasionally occur in an area occupied almost entirely by the other species.

It is evident that there are numerous exceptions to the preceding statement regarding relative distribution of *cornutus* and *chrysocephalus*, and it is significant that these exceptions occur with increasing frequency to the north. Thus, in the Saginaw Bay drainage of Michigan, *cornutus* almost always is the dominant form, regardless of stream size, whereas in Indiana it rarely occurs in any numbers outside of the headwater areas.

Two tributaries of the Huron River, near Ann Arbor, Michigan (Fleming and Mill creeks), contain populations only of *N. cornutus*. At the mouths of these streams dams are present that are effective barriers to upstream movement of *N. chrysocephalus*, a fact emphasized by the abundance of this species immediately below these obstructions. It is interesting to note, that although *chrysocephalus* was common in Mill Creek during the 1930's (UMMZ 55429, UMMZ 64936), five collections made at various localities by Clarence L. Smith and me in June, 1959, yielded 349 specimens of *cornutus* and none of *chrysocephalus*. Although it is possible that a few individuals of the latter species still survive in this stream, the apparent decrease in abundance is notable. Conditions in both Mill and Fleming creeks seem to favor *cornutus*, and the populations of *chrysocephalus* which probably were present originally in both streams were presumably maintained in part by the migration of individuals from the Huron River. The construction of dams apparently stopped this influx, and the residual population, unable to maintain itself in competition with *cornutus*, gradually died out.

Isolated relict colonies of *N. cornutus*, completely surrounded by populations of *N. chrysocephalus*, occur in the Ohio River drainage of southern Indiana and southern West Virginia, far to the south of the main part of the range of this form (Fig. 4). These indicate that *cornutus* was once widespread in the Ohio Valley. It is postulated that, coincident with increased warming of streams, *chrysocephalus* immigrated into this area, where it came into competition with *cornutus*. The two forms occupy similar ecological niches, and since the ecological conditions apparently favored *chrysocephalus*, competition between the two resulted in the elimination of *cornutus*. This hypothesis is supported by the observations of Trautman (1957:357), who has noted this replacement in Ohio: "The post-glacial history of Ohio suggests that both the Northern (*cornutus*) and Central (*chrysocephalus*) Common Shiners were present in some unglaciated portions of the Ohio and/or Mississippi River drainages during glacial times; that in post-glacial times an invasion of both subspecies into glaciated Ohio occurred; that prior to 1800 conditions were

more favorable to the Northern Common Shiner than they have been since, because after 1800 agricultural practices caused the elimination of many springs, the draining of surface waters, the removal of brush and trees along brook banks, thereby allowing the unshaded waters to become warmer and turbidity of the waters to increase; that after 1900 conditions for the Northern Common Shiner became increasingly unfavorable, and became more favorable for the Central Common Shiner; that if this trend continues the Central Common Shiner eventually will replace the Northern Common Shiner in those streams now dominated by the Northern Common Shiner."

The ranges of *N. cornutus* and *N. chrysocephalus chrysocephalus* in Missouri and western Illinois (west of the Illinois River drainage) are completely allopatric (Figs. 4 and 5). Although it is possible that the failure of these species to occur together might be due to chance alone or to lack of adequate collections, these explanations are not entirely adequate. Missouri has been rather thoroughly surveyed, and adequate fish collections exist for Illinois. Furthermore, the interdigitating nature of the ranges of these species, especially in Missouri, indicates that *cornutus* and *chrysocephalus* might have come together at certain times following invasion of this region. The fact that they apparently do not occur sympatrically at present is most likely due to competition.

It is quite possible that the post-Wisconsin invasion by *N. chrysocephalus* of the Great Lakes region represents the first remixing of this species and *cornutus* since the ancestral stock was originally separated, possibly in late Pliocene. This statement is based on the assumption, first, that should there have been periodic remixing following the initial geographical separation, enough gene flow would have occurred to prevent significant morphological changes; and, second, that if the stocks had been reunited later in the Pleistocene (before genetic separation had proceeded as far as it has today), there probably would be evidence of *chrysocephalus* influence within the area now occupied solely by *cornutus*. On the other hand, if differentiation had reached the species level prior to the last (Wisconsin) glaciation, *chrysocephalus* stock which might subsequently have invaded areas where the ecological conditions favored *cornutus* would have been eliminated.

The evidence for specific recognition of *cornutus* and *chrysocephalus* is summarized as follows:

1. Intergrading populations of subspecies normally show a perfect blending of morphological characters, so that a "bell-shaped" curve results from graphic analysis. Although this is approached in some associations containing both *cornutus* and *chrysocephalus*, in other populations the two forms remain morphologically distinct, with few apparent intermediates. In addition, many populations

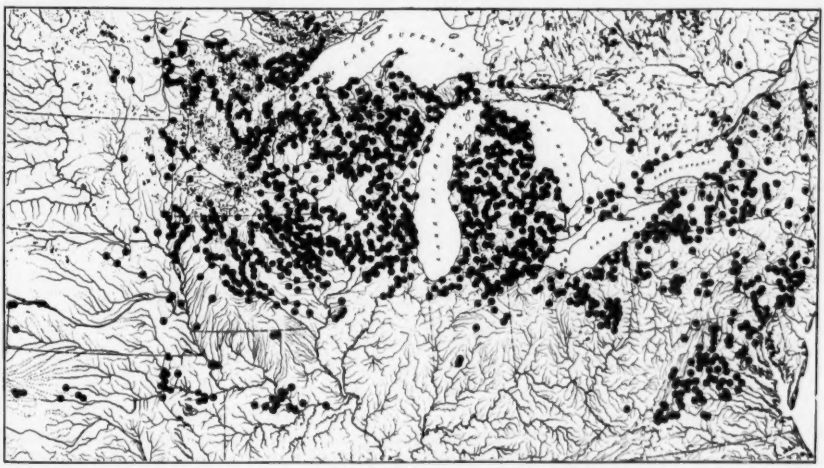

Fig. 4. Distribution of *Notropis cornutus*, excluding marginal limits of range to the west, north and east. Observe particularly relict populations in central Indiana and southern West Virginia.

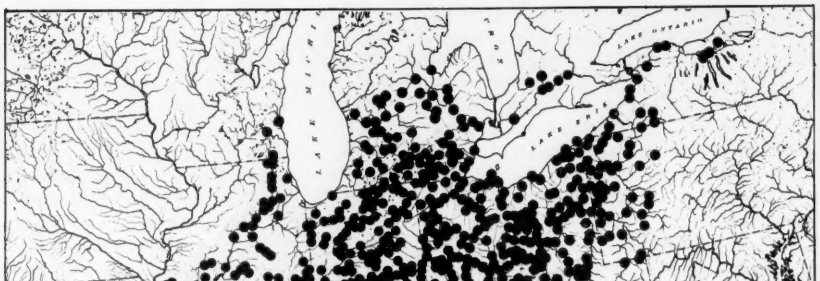

Fig. 5. Distribution of *Notropis chrysocephalus chrysocephalus*, excluding southern part of range. Compare the relative distributions of this species and *Notropis cornutus*.

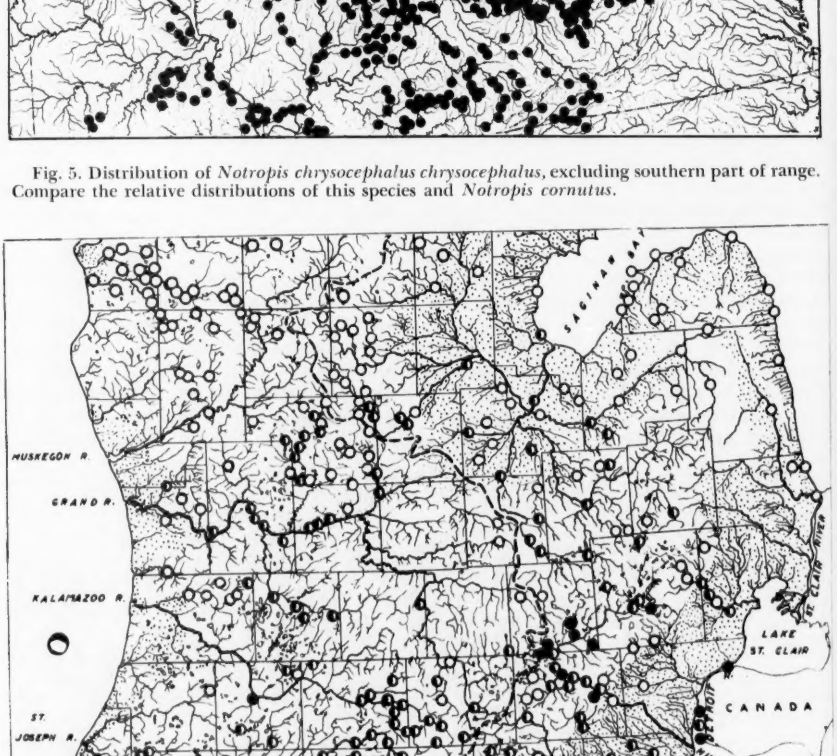

Fig. 6. Distribution of *Notropis cornutus* and *Notropis chrysocephalus chrysocephalus* in southern Michigan, illustrating mosaic pattern which is characteristic of these species throughout region of sympatric occurrence. Hollow circles represent *cornutus* records; solid dots represent *chrysocephalus* records; intermediate circles show localities where both species have been taken together. Collections containing both *cornutus* and *chrysocephalus* have been plotted, regardless of number of specimens. Collections containing just one of the above forms were plotted only when 10 or more individuals were present.

with the zone of "intergradation" contain only one form, a situation that is not concordant with the normal expectation for subspecies.

2. The experimentally-verified differences in temperature tolerance between *cornutus* and *chrysocephalus* are reflected in the northern limits of their respective ranges, and are greater than one might normally expect in subspecies. The apparent preference of *cornutus* for cooler headwater areas and of *chrysocephalus* for the warmer lower reaches of streams is further evidence of this difference.

3. Five collections, consisting of a total of 349 specimens of this complex, taken in Mill Creek, a tributary of the Huron River near Ann Arbor, Michigan, in June, 1959, showed no *chrysocephalus* to be present, although this form had been taken here on a number of occasions in the past. If *cornutus* and *chrysocephalus* were subspecies, it would be expected that the phenotypic character of the population would remain more or less constant.

4. Competition is, in effect, non-existent between subspecies, and where one kind has moved into a region formerly occupied solely by another, intergrading populations occur. The presence of isolated relict populations of *cornutus* far to the south of its principal range, the observed gradual replacement of *cornutus* by *chrysocephalus* in parts of Ohio, and the completely allopatric distribution of *cornutus* and *chrysocephalus* in Missouri and western Illinois is not consistent with the above, and indicates that competition exists where these fish occur together.

5. The distinctive distribution patterns and the imperfect amalgamation of *cornutus* and *chrysocephalus* suggest a long separation, possibly dating back to late Pliocene. This long period of isolation during the Pleistocene could have been sufficient to permit evolution to the species level.

Summary

It has recently become evident that a rigid definition of a species or subspecies is unrealistic, and that the distinction between these taxonomic categories is often a matter of degree and subject to much subjective interpretation. Systematic researches on various groups of North American freshwater fishes have contributed importantly to this reappraisal.

Criteria for the determination of hybrids and intergrades are presented, and pertinent discussions are given of hybridization between members of the families Centrarchidae and Cyprinidae. The relationships between populations of the amphibian, *Rana pipiens,* are also discussed.

Hybrid offspring resulting from crosses between species of the centrarchid genus *Lepomis* agree well in their morphological and physiological characteristics with the criteria cited above. The relationships between certain cyprinids, such as *Notropis cornutus* and *N. rubellus, N. chrysocephalus* and *N. rubellus, N. lutrensis* and *N. venustus, Chrosomus eos* and *C. neogaeus,* and *Carassius auratus* and *Cyprinus carpio,* are not as evident, and are indicative of the complex interactions that may occur. The situation involving *Notropis cornutus* and *Notropis chrysocephalus,* two forms which heretofore have been regarded as subspecies, is extremely complicated. Evidence is presented to indicate a specific relationship between these forms.

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FLORIDA STATE MUSEUM, GAINESVILLE, FLORIDA.

A New Species of Flatfish, *Monolene megalepis,* from Puerto Rico and the Western Caribbean Sea

LOREN P. WOODS

ON various cruises aboard the U. S. Fish and Wildlife Service M/V *Oregon* the author has made extensive collections of fishes at numerous places in the Gulf of Mexico, West Indies, Western Caribbean Sea and Guiana coasts of South America. Many specimens of *Monolene,* family Bothidae, representing the three known western Atlantic species and one undescribed species are included in these collections. The purpose of this paper is to describe this additional species and present a summary of geographic and bathymetric ranges of the four western Atlantic species based only on specimens in the fish collection of the Chicago Natural History Museum.

I wish to thank Mr. Harvey R. Bullis, Jr. of the U. S. Fish and Wildlife Service for permission to join the *Oregon* cruises mentioned above.

Monolene megalepis *sp. n.*

(Fig. 1)

Holotype.—CNHM 65746. West of Arecibo, Puerto Rico, Oregon Station 2663, 18° 30.5′N. Lat., 66°55′W. Long., 43 fathoms, 40 foot semi-balloon trawl, 7 October 1959, 95.4 mm.

Paratypes.—USNM 195859. Same data as holotype, 1 specimen, 88.0 mm. CNHM 65749, a few miles E. of San Juan Harbor entrance, Puerto Rico, Oregon Station 2603, 18°30′N. Lat., 65°59′W. Long., 230 fathoms, 40 foot flat trawl, 25 September 1959, 3 specimens, 68 to 81.4 mm.; CNHM 65748, west of

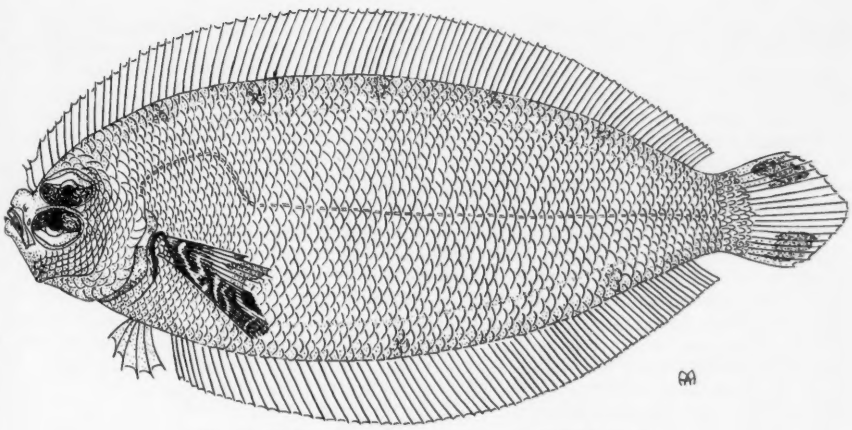

Fig. 1. Holotype, *Monolene megalepis*, CNHM 65746.

Puerto Rico, off Aguadilla, Oregon Station 2653, 18°18′N. Lat., 67°18.5′W. Long., 300 fathoms, 40′ semi-balloon trawl, 6 October 1959, 2 specimens, 80.6 and 82.6 mm.; CNHM 65751, Western Caribbean, 105 miles NE of Mosquito Coast, Honduras, Oregon Station 1867, 16°38′N. Lat., 82°43′W. Long., 140 fathoms, 40 foot flat trawl, 21 August 1957, 2 specimens, 77.2 and 85 mm.; CNHM 65750, Western Caribbean, near Thunder Knoll, Oregon Station 1879, 16°38′N. Lat., 81°39′W. Long., 150 fathoms, 40 foot flat trawl, 22 August 1957, 2 specimens, 86.0 and 91.0 mm.

Diagnosis.—A *Monolene* with only 56–63 large, ctenoid scales on eyed side, scales of blind side cycloid; pectoral fin broad with 17–19 rays, the upper and lower rays longer than those of middle and with lower rays usually longer than upper. Two black oval spots midway on outer caudal rays.

Description.—Counts (Table 1) and proportions of holotype given first followed by range of paratypes in parenthesis: dorsal fin rays 91 (88–93); anal rays 74 (71–74); pectoral rays 19 (17–19); pelvic rays 6 (6); caudal rays iii, 6–6, ii (ii,7–6,ii or iii,6–5,iii); scales in lateral line 63 (56–63), 12 between lateral line and dorsal base, 13 between lateral line and anal base (12–13 above, 13–16 below); gill-rakers 9 on lower limb + 4 on upper (7–10 + 2–5).

Depth of body 2.61 (2.38–2.83), length of head 4.85 (4.34–4.83), snout 27.2 (22.3–26.9), eye 12.7 (12.0–13.3), upper jaw 14.0 (12.3–13.7), length of upper pectoral rays 5.45 (4.80–7.28), length of lower pectoral rays 4.77 (4.41–6.27) length of ventral rays 10.6 (9.25–11.5), length of middle caudal rays 7.06 (4.87–6.17), depth of caudal peduncle 10.3 (9.77–11.0), all in standard length.

Snout with a notch just anterior to upper eye; interorbital a very narrow smooth ridge; premaxillary curved, maxillary extending past anterior margin of lower eye almost to anterior margin of pupil; cheeks and opercles scaled; pectoral fin almost as long as head, all rays simple, upper and lower rays longer than middle (6th) ray, lower rays usually longer than upper rays except in small speci-

Table 1. Meristic Counts of Paratypes of *Monolene megalepis*

	Dorsal rays						
No.	88	89	90	91	92	93	
Freq.	1	3	2	3	1	1	
	Anal rays						
No.			71	72	73	74	
Freq.			2	3	1	5	
	Pectoral rays						
No.				17	18	19	
Freq.				4	4	3	
	Lateral line scales						
No.	56	57	58	59	60	62	63
Freq.	1	1	1	3	1	3	1

mens in which upper and lower rays are about the same length; pelvics on mid-ventral line inserted anterior to base of pectoral; first two gillrakers usually very short and all those on upper limb rudimentary.

Color.—General ground color light grayish to yellowish tan with five small, dark spots spaced along base of dorsal fin and two spots along base of anal fin; vertical fin rays finely barred distally and caudal fin with two large black oval spots on outer rays about midway along fin; pectoral mostly black with variable pattern, a broken white line or broken row of dots on basal one-fourth, white dots on lower half of fin and an ocellated black oval spot in distal one-third of lower half, middle part of upper half usually paler than surrounding parts and tip of upper rays dusky.

Remarks.—Monolene megalepis differs from all other species of the genus in the number of scales in lateral line and in the number of pectoral fin rays. The dorsal and anal rays do not exactly correspond in number with those of any other species but the number of dorsal rays of *M. dubiosa* and *M. asaedae* might overlap *M. megalepis* when more specimens of the two former species are known. *M. megalepis* also differs from all other species in the shape and color pattern of the pectoral fin. No other species of *Monolene* has the distinct dark spots on the caudal fin. Herewith is a key for separating the four western Atlantic species of *Monolene*:

KEY TO THE WESTERN ATLANTIC SPECIES OF *Monolene*

1a	Dorsal rays 88–94, lateral line scales 56–63	*megalepis*
1b	Dorsal rays 96–124, lateral line scales 76–112	2a
2a	Dorsal rays 124, anal rays 100–102	*atrimana*
2b	Dorsal rays 96–107, anal rays 76–88	3a
3a	Head larger 4.2–4.7, eye larger 11.2–15.5, pectoral longer 4.6–8.0	*antillarum*
3b	Head smaller 5.0–5.8, eye smaller 16.3–18.4, pectoral shorter 8.8–10.2	*sessilicauda*

OBSERVATIONS ON DISTRIBUTION

The genus *Monolene* of the lefteye flounder family Bothidae has nine known species including the one described here. Eight of these are American, four species (*M. dubiosa* Garman, *M. danae* Bruun, *M. maculipinna* Garman and *M. asaedae* Clark) live in the eastern tropical Pacific and four in the Western Atlantic (*M. sessilicauda* Goode, *M. antillarum* Norman, *M. atrimana* Goode and Bean and *M. megalepis*). The remaining species, *M. microstoma* Cadenat, is found in the tropical waters off West Africa.

M. sessilicauda frequents depths of 60–200 fathoms in the northern Gulf of Mexico and from North Carolina to off Rhode Island, but has not been reported on either coast of peninsular Florida. Garman (1896) reports *sessilicauda* from Key West, Florida but this specimen, from the description of the pectoral fin color, appears to be *antillarum*. *M. atillarum* has a known range at depths of 85–225 fathoms from Surinam to Barbados and from the Yucatan Channel to Tortugas and the Florida shelf north and west of Tortugas. This species has not been found in the western Caribbean or Greater Antilles. *M. antrimana* lives in somewhat deeper waters, 175–300 fathoms, from northern Brazil to the submerged banks of the western Caribbean. *M. megalepis* so far has been collected on the western Caribbean banks at depths of 140–150 fathoms and in Puerto Rican waters from 43–300 fathoms. *M. atrimana* was trawled 100 fathoms deeper than *megalepis* in the western Caribbean suggesting that where the ranges of two these species overlap they live in different depths. Off the Guianas *atrimana* usually was taken from 175 to 300 fathoms while *antillarum* was usually found in 125–150 fathoms, being taken at 200 fathoms once but not in the same area as stations producing *atrimana*.

M. antillarum (91.5 mm.) has been taken on one occasion with a dipnet at the surface (Oregon Station 1189, Lat. 26°00′N.; Long. 86°05′W.) over 1700 fathoms of water. Bruun (1937) took *M. danae* at Dana Station 1205 II, Lat. 6°49′N.; Long. 80°45′W., in a bathypelagic ringnet at 150–200 fathoms, approximately 1350 fathoms above the bottom. Such habits as noted for these two species may help account for the apparently disjunct distribution of *antillarum*.

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Curator of Fishes, Chicago Natural History Museum, Chicago, Illinois

Developmental Temperature Tolerances of Four Etheostomatine Fishes Occurring in Texas

Clark Hubbs

THE range of temperature tolerance has been ascertained for embryonic and larval stages of few heterothermal vertebrates. Many of the reports pertain to only a part of the total range, usually including the minimum or maximum temperature tolerance, such as Brett and Alderdice (1958) and Bailey (1955). Similarly, the data often concern only a single species such as the papers of Moore (1942, 1949), Anonymous (1951), and Moffett and Randall (1957). Two reports (Embody, 1934; Moore, 1939) include information about several related species. Embody's trout study did not compare developmental survival with reproductive season perhaps because he included data from several stocks obtained at more than one locality. Moore's paper associates survival temperature with reproductive season and shows that, in New York, early (cold temperature) breeding frogs can develop at a lower temperature than do those that breed later (warm temperature). Such a correlation is to be expected, but I find no report of this phenomenon in the fish literature. This study shows that two early spawning species, *Etheostoma lepidum* and *Etheostoma spectabile*, have a far greater tolerance for cold temperatures than two species that spawn later, *Hadropterus scierus* and *Percina caprodes.*

Material and Methods

Adults of the four species were obtained from various localities within a 200 mile radius of Austin, Texas. Although subpopulation differences may have a minor influence on the results, single population plots vary far too little to affect the magnitude of comparison discussed here. Moreover, the few plots available for stocks of *E. spectabile* from Arkansas do not deviate nearly as markedly from local stocks of that species as do plots for local *H. scierus* and *P. caprodes.*

After capture the stocks were returned to Austin and maintained in 2½ gallon glass jars in a water bath (15°C. ± 2°C.). Eggs and sperm were removed by the stripping techniques described by Strawn and Hubbs (1956) or Hubbs (1960). The eggs and young fish were then cultured in enamel trays (Strawn and Hubbs, 1956) or glass dishes (Hubbs and Drewry, 1960). No difference in offspring survival was noted that could be attributed to technique variations. The eggs were placed in a variety of "temperature controlled" situations. The equipment works best at or near room temperature, 18–23°C. At extremely high temperatures, the fluctuations might reach ± 2°C. and at the low range the variation might be ± 4°C. The data presented are, therefore, not as accurate as desired; however, eggs and larvae of each species were exposed to more or less similar thermal history. The average temperature in °C. for each single lot is used. All lots with the same average temperature are pooled. A water bath with a small temperature fluctuation was obtained late in the study period. Unfortunately it usually broke down at critical times and boiled the experimental animals; however, it became apparent that survival at a constant temperature was lower than at a temperature fluctuating about the same point. The results obtained with this equipment are not reported here, but do not

deviate sufficiently to affect the comparisons discussed.

Survival percentages are based on the number of eggs that develop eye pigments divided by the number that complete the larval stages following Hubbs and Strawn (1957a). For precise comparison between species the larval stages are arbitrarily defined to last three times the interval between fertilization and the hatching of the median individuals.

The four species appear to have a similar breeding pattern; however, it has been worked out experimentally only on *E. lepidum* (Hubbs and Strawn, 1957b). The fish have a long spawning season with the males containing sperm over the entire interval. Each female ripens clutches of eggs at intervals dependent upon the environmental temperature. As the spawning period is at least in large part controlled by temperature, the spawning season varies depending upon the temperature of the precise location studied. In general spawning is prolonged in spring-fed streams (constant thermal) as contrasted with others that have a wide thermal fluctuation. Therefore, comparisons must be made where all four species occur together. Only one such locality, the Colorado River at the mouth of Shoal Creek, in Austin, Texas, has been studied extensively. At that locality *E. lepidum* and *E. spectabile* spawn from November through May; *P. caprodes* spawn from January through June; and *H. scierus* spawn from February through June. The terminal dates are less precise than the initial dates because of the increased flow of irrigation water in the river in late spring and summer; nevertheless there is a distinct difference in the spawning periods of the species.

Temperature Survival

Etheostoma lepidum eggs and larvae can survive throughout an interval ranging between 11 and 27°C. (Table 1). The survival

Table 1. Survival of Four Species of Etheostomatine Fishes at Different Temperatures

Temperature	S. Concho *Etheostoma lepidum*		Total *E. lepidum*		Central Texas *E. spectabile*		*Hadropterus scierus*		*Percina caprodes*	
	No. survivors No. fertilized	Percent surviving	No. survivors No. fertilized	Percent surviving	No. survivors No. fertilized	Percent surviving	No. survivors No. fertilized	Percent surviving	No. survivors No. fertilized	Percent surviving
6°C	—	—	0/5	0	—	—	—	—	—	—
7°C	0/2	0	0/2	0	—	—	—	—	—	—
8°C	—	—	0/3	0	0/17	0	—	—	—	—
9°C	0/70	0	0/93	0	—	—	0/5	0	—	—
10°C	0/11	0	0/17	0	1/6	17	—	—	—	—
11°C	29/53	55	32/89	36	0/18	0	0/2	0	—	—
12°C	46/69	67	80/162	49	2/54	4	0/11	0	—	—
13°C	95/147	65	108/200	54	6/21	29	0/49	0	0/12	0
14°C	185/311	59	243/577	42	9/34	26	0/43	0	1/54	2
15°C	82/150	55	151/402	40	9/32	28	0/42	0	0/143	0
16°C	59/145	41	75/245	31	73/247	30	1/25	4	1/116	1
17°C	248/397	62	329/518	64	131/193	68	0/17	0	—	—
18°C	122/227	54	472/1131	42	197/448	44	0/27	0	0/112	0
19°C	170/273	62	862/1741	50	585/1087	54	—	—	2/430	Tr.
20°C	380/515	74	1045/1540	68	106/187	57	0/73	0	0/448	0
21°C	581/761	76	1445/2054	71	54/85	64	2/196	1	0/87	0
22°C	618/735	84	1130/1424	79	702/914	77	14/278	6	43/839	5
23°C	184/238	77	409/921	54	691/1102	63	40/192	21	18/197	9
24°C	109/158	69	209/345	61	356/546	65	5/47	11	6/117	5
25°C	50/150	33	173/401	43	143/262	55	26/114	23	120/381	31
26°C	44/100	44	65/180	36	15/251	6	17/123	14	1/69	1
27°C	10/69	14	10/83	12	4/5	80	4/14	29	—	—
28°C	0/93	0	0/94	0	0/4	0	—	—	—	—
29°C	0/17	0	0/17	0	0/5	0	—	—	—	—
30°C	0/13	0	0/13	0	—	—	—	—	—	—
31°C	0/4	0	0/4	0	—	—	—	—	—	—

percentages are all rather high and little variation occurs throughout the entire range. This resembles Moore's (1949) data on *Rana pipiens*. There is a tendency for high survival at temperatures in the vicinity of 21°C. The figures are more or less comparable whether the data are based only on stocks from the South Concho River four miles south of Christoval or on the entire species sample. There is a slight tendency for data based on stocks from the Nueces River system to do somewhat less well at warmer temperatures, but the deviation appears to be only 1 or 2°C. (Hubbs, 1961).

Etheostoma spectabile eggs and larvae from Central Texas stocks have essentially the same survival range as those of *E. lepidum* (Table 1). The survival of one larva at 10°C. is possibly exceptional. The high survival of the small sample at 27°C. is also obviously a chance variation, especially because the survival of the much larger sample at 26°C. is very low. In fact, it is likely that the survival of local *E. spectabile* at high temperatures is lower than that of *E. lepidum*. The scanty data based on Arkansas stocks of *E. spectabile* also had a wide survival range. Oddly it appears likely that the survival of these northern stocks may occur at higher temperatures than the more southern populations.

Hadropterus sciera eggs and larvae from Central Texas stocks have a much narrower range of thermal survival (Table 1). The survival of one larva at 16°C. is probably due to a chance phenomenon. It was in poor condition when the recording interval passed and died shortly after. Otherwise survivals were over 20°C. and significant survival percentages ranged between 22 and 27°C. This is a narrower range than any I know of and much narrower than the minimum range of 12°C. listed by Moore (1939). The absence of data above 27°C. is not due to lack of experimental effort. Several experiments were set up for those temperatures but no eggs developed, a fact which must be attributed to heat death. It is possible, therefore, that a fish which spawns when temperatures are rising has eggs and larvae adapted to a temperature increase over the developmental interval. Eggs hatched at cooler temperatures will be exposed to warmer temperatures during larval life to test this possibility.

Percina caprodes eggs and larvae have a range of thermal survival similar to that of *H. sciera* (Table 1). Similarly, four individuals passed through the testing interval at low temperatures. They were all weak and died shortly. Otherwise survival was between 22 and 26°C. Eggs in experiments set up for high temperatures did not develop, and it is possible that this species is also adapted to have its eggs and larvae develop over a rising temperature.

The narrow range of developmental survival of *H. sciera* and *P. caprodes* at rather high temperatures explains some questions and poses others. Hubbs and Strawn (1957a) had difficulty explaining their failure to rear *H. sciera* and their low survival of *P. caprodes*. These experiments were carried out at temperatures at or below the survival minimum. Likewise the absence of both species in suitable habitats in the near vicinity of springs (such as those at San Marcos) was unexplained. These spring temperatures do not fluctuate far from 22°C. (Hubbs and Springer, 1957) which approximates their survival minimum. Large numbers of *H. sciera* and occasional *P. caprodes* occur one mile downstream at Thompson Island (Hubbs and Johnson, in press) where the temperature fluctuates between 22 and 25°C. (Brown, 1955). Unexplained, however, is the capture of ripe adults at temperatures far below the developmental survival minimum; *i.e.*, *H. sciera* as low as 12°C., *P. caprodes* as low as 12°C., *E. lepidum* as low as 8°C., and *E. spectabile* as low as 5°C. I suspect that the eggs and more significantly the larvae survive the low average temperatures by carrying out necessary metabolic activities during peak temperatures and merely exist through the cold intervals. The warming would be most effective in the surface film, the habitat of larvae of all the species here discussed except *E. spectabile*.

Conclusion

Two species that spawn during winter and spring have eggs and larvae that can survive temperatures colder than two related species that spawn later.

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The University of Texas, Austin, Texas

Differences in the Incubation Period of Two Populations of *Etheostoma lepidum*

Clark Hubbs

THE rate of development over a wide temperature range has been studied on few fishes. Perhaps the outstanding analysis is that of Embody (1934) who studied the incubation period of four trout species. His analysis was based primarily on "domestic" hatchery stocks. He did allude to possible geographic variations within a species, but such experiments were carried out over only a small fraction of the thermal range. Unfortunately no one has further pursued this aspect of salmonoid biology.

Moore's (1949) analysis of developmental rate in the leopard frog well documents differential rates of development in one species. He showed that five southern stocks developed slower at low temperatures and faster at high temperatures when each was contrasted with developmental rates for northern frogs.

Differences in the incubation period of two samples of greenthroat darters, *Etheostoma lepidum*, from the vicinity of Austin, Texas, are described in this paper. The southern sample develops slower at the middle temperatures and faster at the extremes.

Material and Methods

Adults were obtained from various localities on the Edward's Plateau; greenthroat darters are endemic to this biotic region (Hubbs, 1957). The incubation period of eggs from the Colorado and Guadalupe river systems was contrasted with that of eggs from the Nueces system. This appears to be a natural grouping as Hubbs (1960) and Hubbs and Delco (1960) pointed out characteristics which serve to distinguish the two groups. Two localities, the South Concho River, four miles south of Christoval, Texas, and the East Nueces River, five miles south of Camp Wood, Texas, were sampled extensively and contributed approximately one half of the material studied for each group. Incubation times for the single population samples are

approximately the same as those for the pooled data presented here. The difference is the reduced consistency of the temperature comparisons which are probably due to sampling error.

After capture the stocks were returned to Austin and maintained in 2½ gallon glass jars in a water bath (15°C. ± 2°C.). Eggs and sperm were removed by the stripping techniques described by Strawn and Hubbs (1956) or Hubbs (1960). The eggs were placed in enamel trays (Strawn and Hubbs, 1956) or glass dishes (Hubbs and Drewry, 1960). No difference in incubation period was noted that could be attributed to technique variations. The eggs were placed in a variety of "temperature controlled" situations. The equipment works best at or near room temperature, 18°–23°C. At extremely high temperatures, the fluctuations may reach ±2°C. and at the low range the variation might be ±4°C. The data presented are, therefore, not as accurate as desired; however, comparisons are valid as eggs of each sample were exposed to similar fluctuations at the same temperature range.

Precocious hatching (Hayes, Pelluet, and Gorham, 1953) was not noted in low temperature samples. Its effect, if present, should be equal in each sample.

The eggs were checked daily, usually between 8 A.M. and noon. Time precision was difficult to achieve as often over 300 samples were being checked daily and the time required for each count varied widely. The number hatched was ascertained. The incubation interval is considered to be the time that the median egg hatched. If exactly half of the eggs were hatched when the check was made, the incubation period was considered to be an additional half day. Obviously, accuracy is greatest at the colder temperatures because the interval between checks covers a longer biologic time. The number of days of the incubation period was recorded for each lot as well as the average incubation temperature in °C. The average incubation time was calculated from all of the lots at each temperature. These data are considered as showing the incubation periods for the two samples being compared.

Similarly, incubation periods were calculated for the two hybrid reciprocals. Data are presented here only for those in which ten or more experiments are available at a given temperature.

Incubation Period

The incubation intervals of both samples are plotted (semilog) in Fig. 1. At temperatures between 12° and 21°C. eggs from the Nueces River system hatch about one day later than those from the Colorado or Guadalupe systems. The differences are consistent, and when sample size is adequate the probability of chance occurrence is far less than 1/100. At extreme temperatures, the differences are not as great and the incubation period is shorter in the Nueces system sample than in those from the other streams. The

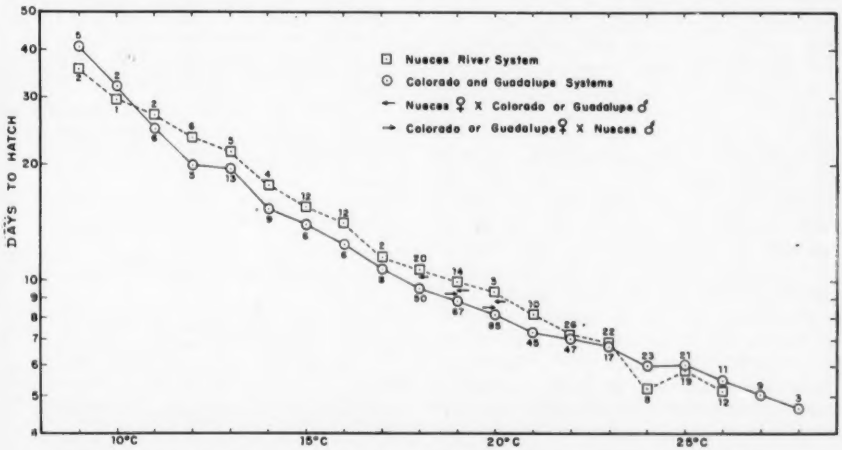

Fig. 1. Average incubation period for two samples of the greenthroat darter, *Etheostoma lepidum*, at several temperatures. The figure beside each point is the number of experiments done at that temperature. Plots for the hybrids are given only for those with ten or more experiments per reciprocal.

difference is of marginal statistical significance at any single temperature.

The change in the relative incubation intervals with temperature may be gradual. Careful examination of the plots indicates two straight segments which break at about 17°C. in the Nueces sample and three straight segments with breaks at about 12°C. and 18°C. in the Colorado and Guadalupe sample. Similar breaks were shown by Embody (1934) for rainbow and brook trout. Moore (1949) drew only straight lines for leopard frog developmental rates; however, his data (Fig. 7) comparing Axtla, Mexico and Vermont samples indicate a break at about 25°C. These breaks may reflect changes between the critical enzymes at different temperatures.

Incubation intervals have been determined for several lots of both hybrid reciprocals. It is not surprising that their developmental rates fall between those of their parents. In general the two reciprocals tend to differ and approach that of their maternal parent. The five instances, in which ten or more lots of a reciprocal were hatched at one temperature, are plotted in Figure 1. Only 19°C. has ten or more lots for both controls and both reciprocals. The four plots are from fastest to slowest, Colorado and Guadalupe control, Colorado and Guadalupe ♀ x Nueces ♂, Nueces ♀ x Colorado and Guadalupe ♂, Nueces control. The significance for each possible relation was determined and four were of much less than a 0.01 probability of being by chance. The two of marginal significance were the difference between the Nueces ♀ x Colorado and Guadalupe ♂ and its maternal control and the reciprocal hybrid. Such maternal influence on developmental rate is not surprising as Newman (1915) showed that early embryology was essentially or entirely controlled by maternal factors and later paternal chromatin influenced the egg. This maternal control of early development may be the reason for the difference between meristic characters of the two reciprocals of atherinid hybrids reported by Rubinoff and Shaw (1960).

The absence of data on incubation periods of Nueces River samples at 26° and 27°C. is not due to experimental effort. The eggs in many experiments set up at those temperatures did not develop or did not hatch. This is thought to reflect a slightly lower maximum temperature tolerance of the Nueces eggs compared with the other greenthroat darter eggs.

Summary

Greenthroat darter eggs from the Nueces River system have a longer incubation period than do those from the Colorado and Guadalupe systems at temperatures between 12°C. and 21°C. At more extreme developmental temperatures 9° to 11°C. and 22° to 26°C. the difference is less pronounced and the Nueces eggs appear to hatch more rapidly than the others.

The hybrid reciprocals tend to approach the developmental rate of their respective maternal controls.

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Department of Zoology, The University of Texas, Austin, Texas

Evolution of Secondary Sexual Characters and Sexual Behavior Patterns in a Family of Viviparous Fishes (Cyprinodontiformes: Poeciliidae)

DONN ERIC ROSEN[1] AND ARLENE TUCKER[2]

THE many adaptable aquarium species of poeciliid fishes have long constituted an important resource for investigations of the interrelations of structure and behavior. Aronson and Clark (1952) and Clark, Aronson and Gordon (1954) summarized the extensive behavioral work on these fishes, and they and Clark and Kamrin (1951) and Hubbs and Reynolds (1957) specifically studied the behavioral significance of fin and genitalic structure in Poeciliidae. Rosen and Gordon (1953) reviewed the mechanics of poeciliid genitalic and fin action in relation to copulatory motor patterns and provided an evolutionary interpretation of their findings. The present paper takes its origin from two separate reports, one behavioral and the other systematic[3]. It concerns the integration of structure and behavior in the evolution of the highly specialized, viviparous poeciliid fishes from a generalized, probably oviparous ancestor. The results of this study show, not unexpectedly, that the combination of comparative studies of behavior and functional anatomy may furnish insights on questions of evolution that do not emerge from either alone. The demonstrable effectiveness of a synthetic approach which was, in fact, a primary incentive for this work, was also the basis for the recent pioneering volume, *Behavior and Evolution* (Roe and Simpson, Editors, 1958), and the symposia on which it was based.

The cyprinodont fishes of the family Poeciliidae have radiated principally from Central America, with lesser centers in the extreme northern Andean region, the Guianas, the Brazilian region, and in Mexico from which a few species have filtered over to the subtropical and boreal United States. Except in tropical Middle-America and some of the Greater Antilles where they are ubiquitous, poeciliids have largely fringing distributions. Many cyprinodonts, in fact, are confined to coastal areas between pure fresh and pure salt water. The relatively unstable coastal environment apparently is inhospitable to the greatly more abundant strictly freshwater fishes and the impinging marine elements, but the cyprinodonts have done well there partly because of a physiological flexibility and the development of brood care, including viviparity.

Poeciliid fishes are particularly suited to studies of sexual behavior for they are small, adapt to aquarium conditions, and abound in sexually dimorphic specializations directly associated with internal fertilization. The structural mechanisms that make possible certain specialized behavior patterns in these fishes during and prior to copulation consist of two principal units: 1) the gonopodium or sexually modified anal fin of the male which serves to transfer sperm bundles to the female genitalium, and 2) the gonopodial suspensorium consisting of a series of complex internal bony supports that are anchored to the axial skeleton. The complex movements of the gonopodium forward and laterally to a copulatory position are made possible by the action of a series of much enlarged and specialized muscles. When a bilaterally symmetrical gonopodium is swung forward from the resting position the elongate bony fin rays and the enveloping web of tissue connecting these rays interact to form a transitory grooved surface along one side of the fin. In a few species a permanent groove along one side of the gonopodium develops during sexual maturation, and such males can copulate from that side only.

MATERIALS AND METHODS

Stocks reserved for behavioral work were maintained in 15-gallon aquaria at a temperature of 23–25°C. From 8 a.m. to 8 p.m. illumination was provided by 30-watt warm white fluorescent bulbs placed 2 to 3 inches

[1] Work done under a National Science Foundation Postdoctoral Fellowship, 1959, at the Genetics Laboratory of the New York Zoological Society.
[2] Work done under a United States Public Health Service Post-doctoral Fellowship, 1957–1959, at the Department of Animal Behavior of the American Museum of Natural History.
[3] Tucker, A. Reproductive behavior in poeciliid fishes. Rosen, D. E. and R. M. Bailey. Zoogeography and evolution of new world cyprinodont fishes of the Family Poeciliidae, with a revision of the genera and materials for a revision of the species. Both manuscripts, now in preparation, incorporate the results of this paper.

above the tank cover. Under these conditions all species reproduced except *Poecilia parae* and *Pseudoxiphophorus bimaculatus.*

Each male-female pair to be studied was placed in a rectangular 7½ gallon aquarium. This measured 14½″ × 10½″ × 10½″, was transparent on the observer's side only, contained a flooring of sand, and was lighted by 15-watt warm white fluorescent bulbs. The male was placed alone in the observation tank for a period of 1–3 days and the female was introduced to him directly from a stock tank immediately preceding an observation period. The observer sat approximately six inches from the transparent aquarium front and recorded the behavior into a Gray audograph. Qualitative aspects of behavior such as movement patterns and relative positions of male and female were noted and the data were quantified in terms of frequency of specific behavior items per five-minute interval of time.

The comparatively large size of *Belonesox* necessitated observation in 15-gallon tanks. The extreme excitability of the female made it necessary to reverse the usual procedure and introduce the male last.

Still photographs of the behavior of *Pseudoxiphophorus bimaculatus, Phallichthys amates, Girardinus falcatus* and *Gambusia affinis* were taken with a 70 mm. sequential camera, set for 16 frames/second with an exposure of approximately 1/350th second under incandescent flood lights. Sets of still photographs representing sequences of behavior were obtained and studied for fine details of fin movements, positions of fish, etc. A 16 mm. movie was taken of reproductive behavior of *Poecilia picta* and the fighting behavior of two males.

The following list includes those genera and species available for this study: *Tomeurus gracilis, Gambusia affinis, Gambusia heterochir, Gambusia manni, Belonesox belizanus, Girardinus falcatus, Quintana atrizona, Heterandria formosa, Pseudoxiphophorus bimaculatus, Poeciliopsis pleurospilus, Phallichthys amates, Poecilia*[4] *(=Mollienesia) sphenops, Poecilia (=Micropoecilia) picta, Poecilia (=Micropoecilia) parae, Poecilia (=Lebistes) reticulata, Poecilia (=Limia) nigrofasciata, Poecilia (=Limia) vittata, Xiphophorus couchianus, Xiphophorus maculatus, Xiphophorus variatus, Xiphophorus montezumae, Xiphophorus pygmaeus, Xiphophorus helleri, Phalloceros caudimaculatus, and Phallotorynus jucundus.*

[4] The genera *Mollienesia, Micropoecilia, Lebistes, Limia* and others are only nominally separable from *Poecilia* (see Rosen and Bailey, 1959). It is more useful here to treat them all as *Poecilia.*

Representative Behavioral Items Defined

I. Activities preceding gonopodial contact:

A. Orientation of male to female. The male moves to a position either 1) directly behind the female, 2) above the female, his head pointing down, or 3) below the female, his head pointing up.

B. Physical contact not involving gonopodium. The male touches his mouth or the pre-orbital region of his head to the genital aperture and contiguous areas of the female. These contacts may occur while the male has his gonopodium in an erected or resting position. If the latter, the gonopodium is immediately erected.

C. Display behavior. The male moves to a point in the water near the head of the female. He performs a display, involving some or all of the following features: special fin positions, contraction of particular muscles altering body shape (such as S-curve), special movements of whole body (such as vibrating, backing, pivoting), changes in color pattern of fins and body.

II. Gonopodial contacts. The following classification pertains to types of gonopodial contacts that can be visually distinguished. Sperm transfer need not occur.

A. Fleeting contact with rapid thrust of body. The male is situated slightly below and very slightly to one side of the female. His body is tilted up, the gonopodium is erected and the tip pointed toward the genital pore of the female. The male propels himself forward and upward beyond and above the body of the female. This is a split-second movement of which only the beginning and end and the direction of movement can be seen clearly; the actual contact of the gonopodium with the female's body cannot. In some species, this type of rapid contact results in fertilization.

B. Fleeting contact not involving thrust of body. The male is located as described in (A) above. He moves forward and upward, lightly touching the erected gonopodium to the ventral surface of the female's body one or more times. The male may move underneath the female to the opposite side, raise himself alongside the female and again

lightly touch the female. He may pass back and forth from side to side several times, lightly touching the female with the gonopodium each time.

C. Prolonged contact of gonopodium with male pushing against female. The male places the tip of the gonopodium on the female's body near or at the genital pore, pushing against her.

D. Prolonged contact with insertion. Starting from positions described in (B) or (C) the male makes prolonged contact with the tip of the gonopodium inserted in the female's genital opening, occasionally when the male and female swim together synchronously. Separation is accompanied by an abrupt movement of the male.

III. Types of gonopodial movement.

Gonopodial swing is defined as the forward movement of the gonopodium followed by its immediate return to the resting position.

Gonopodial erection is defined as the forward movement of the gonopodium and maintenance of the gonopodium in the forward position for a period of about a second or more. Erection occurs during orientation to the female.

Synopsis of Poeciliid Courtship and Mating

Although few poeciliids show in a well-developed state all of the items of sexual behavior that have been recorded for the entire group, each species has some of these incorporated into its repertoire of sexual activities and others into its more generalized behavior patterns (fighting, feeding, swimming). It is possible, nevertheless, to present an account of the manner in which all behavioral items would be sequentially incorporated into a generalized poeciliid pattern of courtship and mating and later to call attention to deletions or other applications of specific items of behavior by each species. In the simplest case where the female is assumed to be receptive, the male orients toward and approaches her. The male may then begin a display involving movements of the body and fins, or he may erect his gonopodium, contact the female with his mouth, fins or body, or perform together or in sequence some combination of these. A gonopodial contact with or without insemination follows. A gonopodial contact without insemination (thrusting of the gonopodium at the genital pore or contiguous areas of the female's body) is followed by a cessation of sexual behavior or the initiation of an entire new sequence of the above items. An insemination, on the other hand, is followed immediately by a spasm and hyperactivity of the male after which sexual behavior may cease or a new sequence of behavior leading to gonopodial contact may be initiated.

The complex maneuvers of the male involve the following shifts in position: 1) an increase in the angle of pitch as measured by the higher position of the head in relation to the tail, which enables the male to perform an upward thrust with its gonopodium; 2) a roll on the horizontal axis, also making possible an upward thrust, but which, in addition, in those species with short gonopodia provides a means of closer approach to the genital region of the female; 3) a pivoting of the body around a point located behind the head, which tends to bring the posterior portion of the body and the erected gonopodium alongside the female's genital region. Thus, when mating, the poeciliid male approaches the female from behind and slightly below. The female is assumed to be stationary or nearly so. The male swings its gonopodium forward and to one side, rolls under the female, pitches upward and pivots inward frequently while throwing its body into a sine-curve. The actual thrust of the gonopodium toward the female is probably accomplished by a stroke of the caudal fin supplemented by the pectoral fin, whereas movements preliminary to this are probably effected primarily by pectoral fin and body muscle action.

Exceptions to this scheme of behavior involve principally those forms (*Pseudoxiphophorus, Poeciliopsis*, etc.) in which a large percentage of gonopodial contacts occurs while the female is in motion. The same number and kinds of maneuvers apparently are performed, but much more erratically and in a broken sequence. Mating in such species is enormously complicated by the superimposed concomitants of forward motion and sudden changes in the direction of this motion; subjectively it seems to demand greater overall mobility, accuracy and coordination than would be required if the female were stationary. All fishes in this category possess long gonopodia, utilize rapid contacts, and in general are more powerful swimmers (see also discussion below, and Gordon, 1955, for a description of mating behavior in *Tomeurus gracilis*).

Analysis

(Tables 1–6)

All of the species may be grouped with respect to whether or not they show specific orientation, mouth or body contact, or display prior to copulatory activity (Table 1). *Poecilia* and *Xiphophorus* typically show all three behaviors. *Gambusia* and *Belonesox* show orientation and display. *Poeciliopsis* and *Phallichthys* show orientation and physical contact. A fourth group typically show only orientation behavior; this is an artificial assemblage of various species possessing certain structural similarities. The relationships between structure and behavior are summarized in Tables 2 to 6, from which we conclude:

1. Absence of physical contact or display behavior, chiefly the latter, prevails in those species possessing long gonopodia and pectoral and pelvic fins that are not sexually dimorphic (*Tomeurus, Heterandria, Pseudoxiphophorus, Poeciliopsis, Phallichthys, Girardinus, Quintana, Phalloceros, Phallotorynus*). Conversely, species with shorter gonopodia and sexually dimorphic pelvic and pectoral fins, although not always making full use of their behavioral repertoire, show a high frequency of physical contact and display preceding copulatory activity (*Gambusia, Belonesox, Poecilia, Xiphophorus*). Tables 2 and 3.

2. Within the family as a whole (as here represented by 13 genera) apparently there is no strong correlation between sexual dimorphism in color patterns and use of physical contact and/or display during courtship. This surprising conclusion is based upon the following observations (Table 4):

a. physical contact and display are characteristic of all *Poecilia*-like fishes so far studied. Of them, only 6 (*Xiphophorus helleri, X. montezumae, X. variatus, Poecilia parae, P. picta* and *P. reticulata*) show a high-level pigmentary dimorphism; the remainder show a low-level dimorphism that is characteristic of most poeciliids.

b. physical contact and display typify all *Gambusia*-like fishes studied (*Gambusia affinis, G. manni, G. vittata, G. puncticulata, G. heterochir, Belonesox belizanus*) and they all show a low-level sexual dimorphism in pigmentation.

c. physical contact is rare and display wholly absent in all other poeciliids studied, and these too show a low-level color dimorphism like that of *Gambusia* and some poecilid.

3. Again at the family level, there is no apparent correlation between gonopodial length and type of terminal modification in the gonopodium (Table 5), nor are the terminal gonopodial structures at present clearly related to types of physical contact and display.

The fine details at the tip of the male's gonopodium (spines, serrae, hooks, etc.) are

Table 1. Typical Precopulatory Behavioral Repertoire in 13 Genera of Poeciliid Fishes[1]

	Specific Orientation	Mouth or Body Contacts	Display
Poecilia	X	X	X
Xiphophorus	X	X	X
Gambusia	X	—	X
Belonesox	X	—	X
Poeciliopsis	X	X	—
Phallichthys	X	X	—
Heterandria	X	—	—
Pseudoxiphophorus	X	—	—
Quintana	X	—	—
Girardinus	X	—	—
Phalloceros	X	—	—
Phallotorynus	X	—	—
Tomeurus	X	—	—

[1] See Introduction for the species represented in each genus.

Table 2. Relationship between Length of External Male Genitalium and the Typical Precopulatory Behavioral Repertoire in 13 Genera of Poeciliid Fishes

	Specific Orientation	Mouth or Body Contacts	Display
Gonopodium long	*Poeciliopsis*	*Poeciliopsis*	—
	Phallichthys	*Phallichthys*	—
	Heterandria	—	—
	Pseudoxiphophorus	—	—
	Quintana	—	—
	Girardinus	—	—
	Phalloceros	—	—
	Phallotorynus	—	—
	Tomeurus	—	—
Gonopodium short	*Poecilia*	*Poecilia*	*Poecilia*
	Xiphophorus	*Xiphophorus*	*Xiphophorus*
	Gambusia	—	*Gambusia*
	Belonesox	—	*Belonesox*

TABLE 3. RELATIONSHIP BETWEEN PECTORAL OR PELVIC FIN MALE SECONDARY SEXUAL SPECIALIZATIONS AND THE TYPICAL PRECOPULATORY BEHAVIORAL REPERTOIRE IN 13 GENERA OF POECILIID FISHES

	Specific Orientation	Mouth or Body Contacts	Display
Paired fins not sexually dimorphic	*Poeciliopsis*	*Poeciliopsis*	—
	Phallichthys	*Phallichthys*	—
	Heterandria	—	—
	Pseudoxiphophorus	—	—
	Quintana	—	—
	Girardinus	—	—
	Phalloceros	—	—
	Phallotorynus	—	—
	Tomeurus	—	—
Paired fins sexually dimorphic	*Poecilia*	*Poecilia*	*Poecilia*
	Xiphophorus	*Xiphophorus*	*Xiphophorus*
	Gambusia	—	*Gambusia*
	Belonesox	—	*Belonesox*

TABLE 4. RELATIONSHIP BETWEEN HIGH- AND LOW-LEVEL MALE SECONDARY SEXUAL COLORATION AND THE TYPICAL PRECOPULATORY BEHAVIORAL REPERTOIRE IN 13 GENERA OF POECILIID FISHES

	Specific Orientation	Mouth or Body Contacts	Display
Low-level pigmentary dimorphism	all genera	*Poecilia*	*Poecilia*
		Xiphophorus	*Xiphophorus*
		Poeciliopsis	*Gambusia*
		Phallichthys	*Belonesox*
High-level pigmentary dimorphism	*Poecilia*	*Poecilia*	*Poecilia*
	Xiphophorus	*Xiphophorus*	*Xiphophorus*

related to activities during the actual copulatory contact, however. Transfer of sperms as spermatophores may occur in at least two ways. Either they are inserted directly into the genital pore of the female or they are deposited externally on or near her genital pad and the sperms once freed from the spermatophores move into the genital opening. Direct insertion of sperms requires insertion of the gonopodial tip, and this appears to be the usual method in *Xiphophorus* and *Poecilia* (Clark, Aronson and Gordon, 1948, 1949, 1953; Clark and Aronson, 1951; Aronson and Clark, 1952) and perhaps in *Gambusia* also (see Warburton, Hubbs and Hagen, 1957, reference to prolonged contacts). Such forms have developed at the tips of their gonopodia hooks, spines, and claws that may serve as holdfasts securing contact between the sexes during sperm transfer. Clark and Rosen (*in* Rosen and Gordon, 1953), for example, illustrated how

TABLE 5. RELATIONSHIP BETWEEN LENGTH OF EXTERNAL MALE GENITALIUM AND KINDS OF TERMINAL GENITALIC STRUCTURES[1]

	Terminal hooks, claws or teeth (holdfasts?)	Ventral spines (sensory receptors?)	Subradial fleshy or bony processes (sensory receptors?)
Gonopodium long	*Heterandria*	*Girardinus*[2]	*Girardinus*
	Pseudoxiphophorus	*Tomeurus*	*Phalloceros*
	Quintana	—	*Phallotorynus*
	Girardinus	—	*Tomeurus*
Gonopodium short	*Poecilia*	*Poecilia*	*Poecilia*
	Xiphophorus	*Xiphophorus*	—
	Gambusia	*Gambusia*	—
		Belonesox[2]	—

[1] The gonopodium in *Poeciliopsis* and *Phallichthys* is permanently folded to one side, and most terminal specializations are reduced or absent. In *Quintana* only a few segments are permanently asymmetrical. All other genera studied are bilaterally symmetrical.

[2] Spines very poorly developed

removal of one or the other of two assumed holdfasts in *Xiphophorus* materially reduced the system's efficiency, and how the complete removal of both prevented insemination from occurring. Moreover, Clark, Aronson and Gordon (1953) demonstrated that species of *Xiphophorus* with larger gonopodial holdfasts (*X. helleri*) have longer copulatory contacts than those (*X. maculatus*) in which they are less developed. These authors noted that some of the swordtail females bled from their genital openings following withdrawal of the gonopodial tip. In *Tomeurus* the extraordinarily complex series of modifications at the tip of its gonopodium (Fig. 1) serve in some manner to deposit spermatophores on the genital region of the female (Gordon, 1955). Copulatory contacts as in *Poecilia, Xiphophorus, Gambusia* and *Belonesox* are prolonged, in *Tomeurus* instantaneous. Rapid contacts may frequently signify absence of a true insertion. In *Pseudoxiphophorus,* in which contacts appear to be wholly of this kind, we have observed a large, probably distensible, foliate genital pad in the female upon which spermatophores may be effectively trapped. In general, however, precise information is wanting on this critical phase of poeciliid sexual behavior.

4. The numbers of right and left erections, swings and contacts, and therefore approaches and display, are statistically equal in all species with bilaterally symmetrical genitalia. The matter is different in species in which these structures are asymmetrical. Over 90 percent of erections are sinistral in *Quintana,* a species in which only a few segments in the gonopodium are twisted to the left. in *Phallichthys,* a species with the entire gonopodium permanently folded to the left, 100 percent of the erections are sinistral. In both, swinging behavior per se appears not to be affected by structural asymmetry, although the degree of the swing to either side not noted here may reflect direction of permanent folding of the gonopodial rays. Table 6.

Discussion

Elaborateness of precopulatory behavior patterns in the poeciliid fishes is related to relative length of the male genitalium (gonopodium) and the presence or absence of pelvic or pectoral fin specializations that assist gonopodial action (see above). For reasons now to be discussed it is possible that differences in the sexual behavior patterns and component sexual activities of species with long and of species with short gonopodia involve the differential utilization of visual, tactile and kinesthetic stimuli to accomplish the successful transfer of sperms.

In forms with extremely long gonopodia (*Pseudoxiphophorus, Girardinus,* etc.), the tip of the erected fin reaches to or beyond the eye. Such fishes in all probability are aided principally by visual cues in orienting themselves and localizing gonopodial contact with the female. Presumably they can see

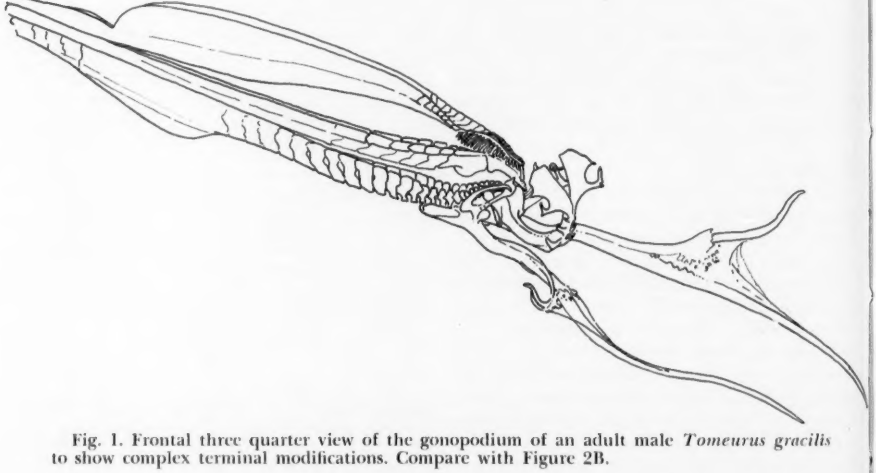

Fig. 1. Frontal three quarter view of the gonopodium of an adult male *Tomeurus gracilis* to show complex terminal modifications. Compare with Figure 2B.

TABLE 6. RELATIONSHIP BETWEEN STRUCTURAL SYMMETRY OF THE GONOPODIUM (EXTERNAL MALE GENITALIUM) AND FREQUENCY OF GONOPODIAL SWINGS AND ERECTIONS TO THE RIGHT OR LEFT IN THREE SPECIES OF POECILIID FISHES[1, 2]

Species	Gonopodium	No. 30 to 50 minute observations	No. males observed	Total Erections			Total Swings		
				Left	Right	Not determined	Left	Right	Not determined
Heterandria formosa	Bilaterally symmetrical	16	16	163	163	77	72	69	11
Quintana atrizona	Few segments on one ray sinistrally asymmetrical	11	7	138	7	122	29	30	24
Phallichthys amates	Sinistrally asymmetrical	13	11	11	0	0	41	37	0

[1] Males observed with a single female.
[2] No account is taken here of dextral or sinistral bias of individual males.

their own erected gonopodia and the target area on the female (Figs. 2A, B) and presumably also this admits the possibility of a certain flexibility in the behavior of the female. She need not always assume a single ritualized attitude inasmuch as males of these species can visually adjust their approaches and contacts with a versatility and speed not apparent in forms with shorter gonopodia. Although it is probable that not all forms with long gonopodia consummate sperm transfer with equal abruptness, *Pseudoxiphophorus* and *Phallichthys* do so with such rapidity that a high speed sequential camera did not record the event. This calls for a precision of action that may only be possible in species that are primarily visually oriented during copulatory activity.

In forms with shorter gonopodia (*Poecilia, Xiphophorus, Gambusia, Belonesox*), the tip of the erected fin is displaced relatively so far behind and below the eye that visual cues probably are not of primary importance to the fish in localizing gonopodial contact. Here structures are developed that aid in positioning and stabilizing the gonopodium following its erection and that may provide specific tactile stimuli during copulatory contacts. In *Gambusia*, the notched pectoral fin is moved obliquely downward and the gonopodium is brought forward underneath[5] this fin where its position is localized by the notch in the pectoral fin's leading rays (Figs. 3B–D). In some species of *Poecilia* and in *Xiphophorus* the erected gonopodium rests against the underside of a raised pelvic fin (Fig. 3A) (Clark and Kamrin, 1951), whereas in some endemic West Indian *Poecilia* the gonopodial tip is actually inserted in a notch between pelvic rays 2 and 3. With the gonopodium thus fixed in position, the fish can bring into play visual cues for orienting its body in relation to some species-specific color marking or solid structure on the female. After this initial orientation, perhaps largely dependent upon a combination of kinesthetic and visual stimuli, the male may then have to rely wholly or in part on stimuli received from a tactile organ either on the gonopodium and/or an accessory fin. In *Gambusia* the tip of the fixed pectoral fin may possess tactile properties. In *Poecilia* fleshy appendages at the tips of the gonopodium and pelvic fin that have specific innervation may provide sensory cues for the male, whereas in *Xiphophorus* spinous processes on gonopodial ray 3 and the fleshy tips of pelvic rays 1 and 2 may be sensory receptors (see Rosen and Gordon, 1953). The fulfillment of all of these preparatory maneuvers is a comparatively slow process as compared with the preliminary orientation in species with long gonopodia. In forms with short gonopodia even copulation is a comparatively drawn-out affair, typically lasting anywhere from one to four seconds. The time required by the male to effectively integrate and utilize the various sensory cues suggests a need

[5] Hubbs (1957) and Hubbs and Reynolds (1957) claim that the gonopodium is placed *over* the pectoral. Our photographs do not support this.

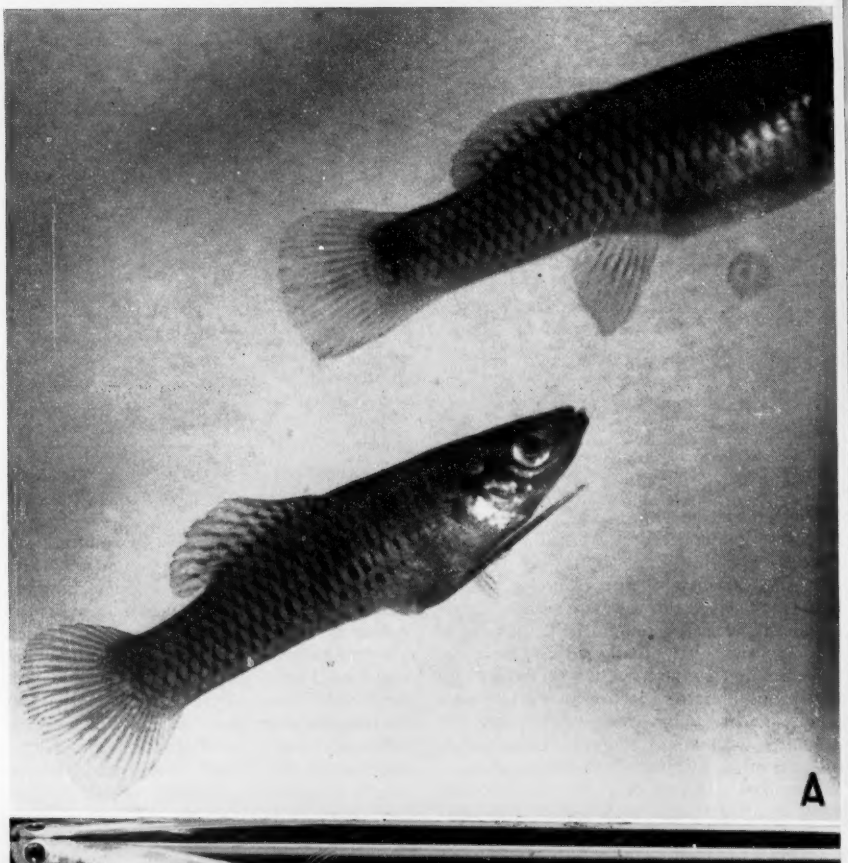

Fig. 2. A. Male and female *Pseudoxiphophorus bimaculatus*. B. Male and female *Tomeurus gracilis*. In each case, the male, below, is preparing for a thrust. His long gonopodium, which is approaching full erection, will soon extend up along one side of his body where the gonopodial tip will be just below his eye. When at rest, the gonopodium extends backward along the underside of the male's body. The photograph of *P. bimaculatus* is taken from a high speed still sequence that terminated with an actual contact of male and female.

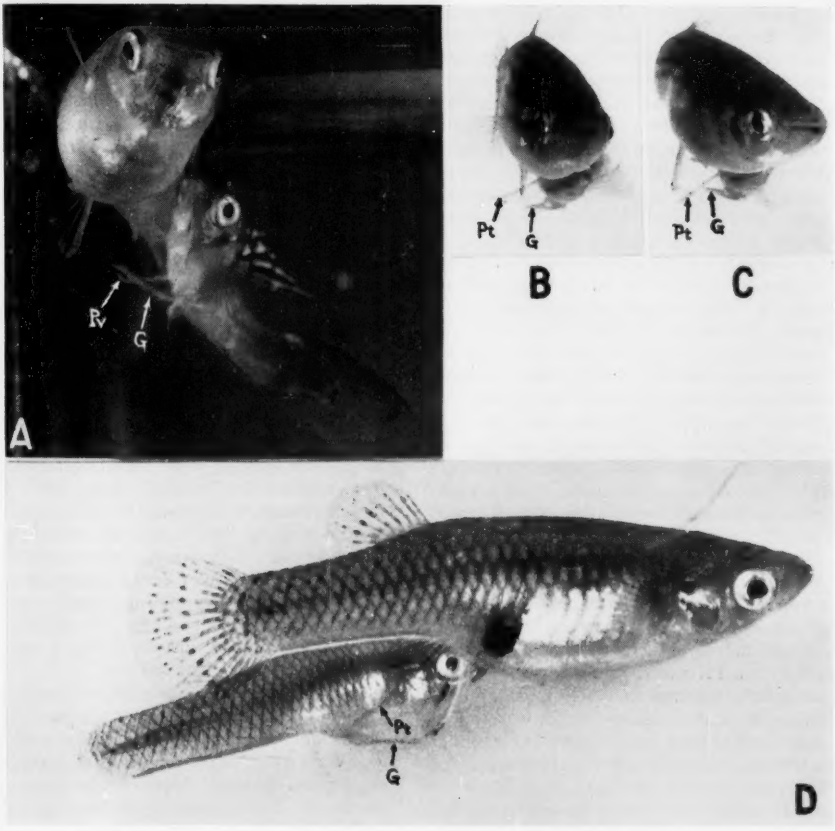

Fig. 3. A. Head on view of a male and female *Poecilia reticulata* during thrusting behavior. B. and C. The same for *Gambusia affinis*, B immediately preceding C is a high speed still sequence. Note similar use of pelvic fin (Pv) and pectoral fin (Pt) in relation to the partially erected gonopodium (G) of the male in these two unrelated species with short gonopodia. D. Side view of a male and female *Gambusia affinis* during thrusting behavior. The relative positions of the two sexes and orientation of the pectoral fin and gonopodium of the male are comparable to those in B. These two poeciliid species apparently have solved the same functional problem using a non-homologous combination of fins.

for a rather stable, ritualized behavior on the part of the female, and indeed females of *Gambusia, Belonesox, Poecilia* and *Xiphophorus* appear to assume and maintain within rather wide limits a characteristic motor pattern in relation to the male[6]. Body and mouth contacts and display prior to copulatory activity are confined entirely to members of these four genera (within the limits of this study), and these preliminary activities on the part of the male may serve specifically to call forth the essential and ritualized behavior of the female. A high-level sexual dimorphism in color pattern, found only in some species of *Poecilia* and *Xiphophorus*, may be an additional evocator of the appropriate female response[7].

There exists some indirect evidence that *Gambusia* and *Poecilia* are more recently evolved than most or all other poeciliid gen-

[6] This study has dealt primarily with the male. Observations on females have been incidental and we are here able to report only general qualitative information.

[7] Although male activities may evoke an appropriate female behavior that increases the probability of copulation and insemination, an *active* cooperation on the part of the female is not implied. The evoked receptivity of the female may be no more than a slowing down or stopping, thereby permitting the male to orient himself and set his gonopodium for a thrust.

era (Rosen and Bailey, ms.). If so, it is possible that elaborate mating displays, as here restricted to members of *Poecilia, Xiphophorus, Gambusia,* and *Belonesox,* are comparatively recent innovations in the family. What, then, may have been the distant historical relationships of the adaptive lines that eventually led to groups of poeciliids with the diverse structural and behavioral modifications associated with long and short gonopodia?

Ancestral poeciliids may well have been structurally similar to some contemporary oviparous cyprinodonts, except for the anal fin that probably was differentiated into a generalized type of external genitalium. Oviparous species with their already rather complex repertoire of behavioral activities (S-curving, physical contact and display, interlocking of fins, and use of anal fin to localize the flow of sperms) are psychologically, as well as anatomically, preadapted to the evolution of a mechanism for internal fertilization (see Newman, 1907; Amemiya and Murayama, 1931; Rosen and Gordon, 1953). The development of a gonopodium, of course, insures fertilization by restricting the process to the narrow confines of the female's genital region. But such a mechanism is not necessarily more efficient than external fertilization of the egg, provided that specific mating behavior patterns and the environment are combined to favor this more usual method. For small fishes living under fluviatile conditions or in tidal embayments, however, the development of a specific structure to localize the flow of sperms to the egg would have adaptive value. If, for example, one such solution to the problem of fluviatile fishes were the ability to create a transitory concavity in the anal fin as it is brought forward and to one side, as have some species of the oviparous genus *Aphyosemion* (Kosswig, 1948), and if the next step were the ability to raise the fin to a point under the female's genital pore, it would involve only a few more steps and not very large ones, to the eventual evolution of a generalized type of gonopodium. Rosen and Gordon (1953) have detailed some possible intermediate conditions that could have led to the complex type of poeciliid genitalium.

Poeciliids today, however, differ from all groups of oviparous cyprinodonts in the more anterior insertion of the anal fin. The significance of this is probably twofold. The anterior displacement of the anal fin brings it into closer alignment with the fish's center of gravity[8], a factor that would become increasingly important as this fin assumed a new mobility and as the need for orienting it precisely in relation to a comparatively small target area (female genital pore) arose. Migration forward of the anal fin would also bring it closer to the fish's central visual field to make possible more complete control over its use. At some intermediate point in such a continuum of change from the posterior to the anterior type of anal fin insertion two primary alternatives lay open. On the one hand, the gonopodium could be lengthened to a point where its erected tip was fully visible to the fish. This, as a change requiring only a comparatively minor alteration of developmental rates (Rosen and Bailey, ms.), appears to have been exploited by most poeciliid groups as represented today by over 80 percent of the recognized genera. On the other hand, the gonopodium could have been gradually shifted still farther forward in the body, a complex change involving many different tissues and organs. Such a change would be slower to occur (Rosen and Kallman, 1959) allowing plenty of time for the evolution of complex courtship and mating patterns and accessory structures that enhance the effectiveness of what initially must have been a comparatively ineffectual mechanism.

Attention should be directed to the fact that the process of lengthening the gonopodium is not incompatible with shifting the entire fin farther forward, for each change complements the other. Moreover, both modifications are incorporated by *Tomeurus* and *Cnesterodon* (Rosen and Kallman, *Ibid.*). Such fishes may still be grouped with, and behave like, other poeciliids with long gonopodia, for it appears that gonopodial length *per se* is primarily correlated with the complexity of the behavioral repertoire.

Elaborate preparatory displays, bilateral pectoral and pelvic fin modifications and occasional color dimorphism appear to have evolved as enhancers of the effectiveness of the short type of gonopodium. This type of gonopodium is bilaterally symmetrical and can be erected to the right or left side, forming a transitory closed or partially closed tube. In many forms with long gonopodia the anal

[8] Actually, anterior displacement of the gonopodium brings this fin into alignment with that portion of the fish's body around the pivoting point. This region of the fish's body travels directly forward without oscillating during forward progression. It was termed by Breder (1926) the *orthokinetic part*, and includes the center of gravity or center of mass (see also Harris, 1936). It is obviously that portion of the body having the greatest stability and allows utilization of the gonopodium almost independently of motions of the head and tail of the fish.

rays have become permanently folded to one side; mechanically this constitutes a highly adapted vehicle for sperm transfer by ensuring proper closure of the sperm groove. Because poeciliid fishes with bilaterally symmetrical genitalia can create a transitory tube on the right or left side at each copulatory attempt all species are in a sense preadapted to the evolution of a permanently folded genitalium (Rosen and Bailey, 1959). Permanent folding permits structural modification to enhance the effectiveness of the mechanism. The absence of gonopodial asymmetry in species with short gonopodia may indicate that their developmental pathways are so strongly canalized to produce complex accessory bilateral mechanisms that even slight asymmetric distortions would be inadaptive and therefore quickly eliminated. Although structural asymmetry when present exerts a profound influence on the manner in which the fish may erect his fin, it appears not to affect seriously the direction of swinging and other behaviors. Since laterality is strongly impressed on some behaviors only, it is possible that the species-specific asymmetric behavior of some poeciliids is a direct result of peripheral structural limitation.

Summary

Elaborateness of precopulatory mating behavior in the members of 18 genera of poeciliid fishes is found related to the length of the external male genitalium (modified anal fin or gonopodium) and the presence or absence of specializations of the paired fins that assist gonopodial action. It is suggested that the underlying difference between the sexual behaviors of species with long and short gonopodia involves the differential utilization of visual, tactile and kinesthetic stimuli necessary for the successful transfer of sperms.

It is noted that the viviparous Poeciliidae differ from all groups of oviparous cyprinodonts in the more anterior insertion of the anal fin. Its forward shift in the body brings the gonopodium into closer alignment with the fish's center of gravity and its central visual field, thus enabling the fish to exercise more complete control over its use during the complex mating maneuvers. During the evolution of the anterior type of anal fin insertion, the effectiveness of the gonopodium may have been further enhanced by 1) a pronounced elongation of the genitalium itself, and/or 2) the development of bilateral accessory structures and tactile organs that greatly aid positioning and stabilizing a shorter gonopodium during erection.

Males of species with long gonopodia may be primarily visually oriented and may therefore be able to contact the female while she is in motion. Males of species with shorter gonodopia may rely more heavily on kinesthetic and tactile cues; copulatory contacts are typically made while the female is stationary. In the latter forms, elaborate display and occasional male secondary sexual coloration may evoke in the female a response to slow down or stop.

Whereas elaborate preparatory display, color dimorphism and modifications of the paired fins have evolved so that they enhance the effectiveness of the short type of gonopodium, permanent structural asymmetry may have arisen for the same reason in the long gonopodium. A profound influence of asymmetry of the gonopodial system on certain behavioral items is demonstrated.

Acknowledgments.—For their criticism of the manuscript and suggestions during the work we are grateful to Lester Aronson, Charles M. Breder, Eugenie Clark, Coleman Goin, Daniel Lehrman, William J. Riemer, Jay Rosenblatt, Theodore Schneirla, and Evelyn Shaw. Lee Boltin, Henry Lester, and Elwood Logan provided valuable photographic aid. A 70 mm. sequential camera was provided by *Life Magazine*. Laboratory space was made available by the Department of Animal Behavior of the American Museum of Natural History. Figure 2B is a New York Zoological Society photograph by Sam Dunton, and Figure 3A is from Clark and Aronson (1951).

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FLORIDA STATE MUSEUM AND DEPARTMENT OF BIOLOGY, UNIVERSITY OF FLORIDA, GAINESVILLE, AND INSTITUTE OF ANIMAL BEHAVIOR, RUTGERS THE STATE UNIVERSITY, NEWARK, NEW JERSEY.

Studies on Fishes of the Family Ophidiidae—VI.
Two New Genera and a New Species from American Waters[1]

C. RICHARD ROBINS

CONTINUING studies on ophidiid fishes demonstrate that two species currently placed in *Lepophidium* belong elsewhere, one to a different subfamily. New genera are described below to house these species. A new species of *Lepophidium* from the Atlantic Coast of northern South America is also described.

This report is based on work supported by the National Science Foundation (NSF-G-7116). I am grateful to Loren P. Woods (Chicago Natural History Museum), Giles W. Mead and Harvey R. Bullis, Jr. (U. S. Fish and Wildlife Service), Leonard P. Schultz and Ernest A. Lachner (U. S. National Museum), Richard H. Rosenblatt and Carl L. Hubbs (Scripps Institution of Oceanography), Margaret Storey (Stanford Natural History Museum) and Vladimir Walters (American Museum of Natural History) for providing materials and facilities at their institutions. Robert R. Rofen was especially helpful during the writer's visit to Stanford. Paulo de Miranda Ribeiro and Antenor Leitao de Carvalho generously loaned two cotypes of *Lepophidium fluminense* from the Museu Nacional at Rio de Janeiro. Jo Ann Rose prepared Fig. 1 and processed data; Walter R. Courtenay prepared the photographs and X rays.

[1] Contribution No. 308 from The Marine Laboratory, University of Miami.

Raneya gen. n.

Diagnosis.—A genus of the subfamily Ophidiinae with which it shares a staggered (anguilloid) arrangement of scales, an absence of pyloric caeca, and general body form (the body rather blunt, the caudal region rounded, not pointed). Squamation well developed (the body entirely scaled), the scales imbricate, and becoming somewhat imbedded on the chest and along bases of vertical fins. Pectoral-fin base naked. Nape and occiput fully scaled, the scales round and non-imbricate; interorbit partly scaled. Opercle naked; area from border of preopercle forward to orbit and the suborbital region scaled. Maxillaries, lower jaw, throat and preorbital regions naked. A stout, horizontally directed opercular spine present.

Rostrum with prominent, anteriorly curved and pointed spine, upright as in *Otophidium*. Gas bladder in female with distinct lateral outpocketings along its entire length (Fig. 1). Esophagus black, hind gut dark, gill chamber very dark. Maxilla with mid-dorsal protuberance followed by a shallow notch. Supramaxilla with a prominent ventral projection (Fig. 2b).

Type of genus.—*Lepophidium fluminense* Alipio de Miranda Ribeiro, 1904.

Name.—For Edward C. Raney, who first introduced ichthyology to the writer.

Raneya fluminensis (Miranda Ribeiro)

Fig. 1–2

Lepophidium fluminense A. de Miranda Ribeiro, 1903:44–45 (description; type locality: ESE of Ilha Rasa, Brasil). P. de Miranda Ribeiro, 1953:402 (6 cotypes in Museu Nacional, No. 1890). Robins, 1959: 366 (Name only).

Lepophidium brevibarbe, A. de Miranda Ribeiro, 1915:[717], fig. opposite p. [708] (original description of *fluminense* repeated; the species now called *brevibarbe* without comment). Fowler, 1941:180 (In part, the Ilha Rasa record only).

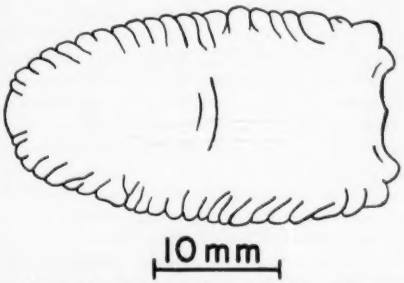

Fig. 1. Ventral view of gas bladder of *Raneya fluminensis* (Ribeiro). Based on a female lectoparatype, 211 mm. standard length, National Museum of Brazil, No. 1890.

Material examined.—Two specimens, (females) standard lengths 97 and 211 mm., from the series of 6 cotypes (National Museum of Brazil, No. 1890) are available for study. The description below is based largely on the larger specimen except as noted. Neither counts of vertical fin rays nor body proportions were determined from the smaller specimen because of its poor condition.

Description.—Dorsal rays 133, anal rays 109, caudal rays 9 (4 above, 5 below), pectoral rays 22–22, 23–22, gillrakers 6 (2 rudiments on the upper limb, 4 developed rakers below in both specimens), branchiostegal rays 7. Precaudal vertebrae 15, 15; caudal vertebrae 51, 50; total vertebrae 66, 65 (smaller specimen last).

Body proportions in hundredths of standard or (*) head length: head length 22, predorsal distance 26, preanal distance 41, snout tip to occiput 16, postorbit (to tip of opercle) 13, orbit diameter *28, bony interorbit *18, snout length *17, maxillary length (from juncture of premaxillaries) *37, pectoral-fin length 9.4, longer pelvic element 6.9, shorter pelvic element 4.4, body depth at (1) occiput 12, (2) dorsal-fin origin 13, (3) anal-fin origin 12, caudal-fin length 5.7, lateral-line length (from snout tip) 90.

Peritoneum silvery, mouth pale, esophagus and gill chamber black or very dark, hind gut dark. Vertical fins with continuous narrow dark margin, perhaps black in life; dark margin on dorsal fin perhaps interrupted (the specimen is worn and faded but interruptions are evident in Ribeiro's figure).

No trace of the barred and spotted pattern described from fresh specimens by Ribeiro (1904:45) and partly evident in his figure (1915: unnumbered figure labeled *Lepophi-*

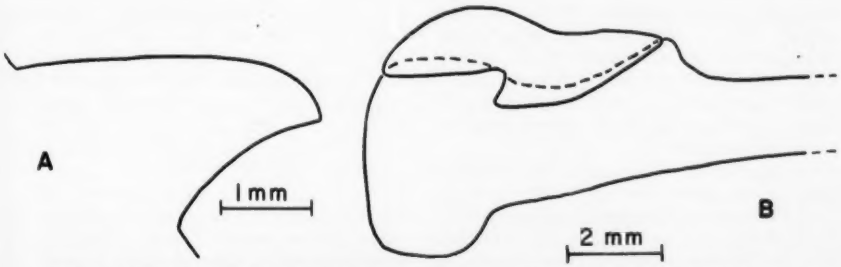

Fig. 2. Lateral view of (a) ethmoid spine and (b) maxillary and supramaxillary bones of *Raneya fluminensis* (Ribeiro). Specimen as in Fig. 1.

dion [*sic*] *brevibarbe*) was noted in the preserved material.

Body (behind head) completely scaled; about 140 reasonably regular rows between caudal-fin base and shoulder. Scales larger anteriorly, smaller caudally. Scales on body mainly oval, varying from nearly round (especially caudally) to very elongate. Each scale overlapping the scale behind and the one above. Rows on caudal third of body most regular approaching in pattern that of members of the Lepophidiinae. On middle section of body orientation of long axis of scales reverses from row to row but is uniform within a row. Anteriorly, orientation alternates within the row as well as between rows and the typically anguilloid ophidiine pattern is evident.

Opercle, snout, jaws, chin, and branchiostegal regions naked. Occiput completely covered with circular, non-imbricate scales. Interorbit naked anteriorly and along its midline, scaled laterally on its posterior two-thirds. Cheeks (to preopercular margin) and suborbital region (to under anterior margin of pupil) covered with non-imbricate scales of varying shape.

Anterior nostril tubular (the tube short), posterior nostril an oval opening midway between anterior margin of orbit and anterior nostril. Subnasal pit with a few fleshy flaps but snout and preorbital rim not decorated.

Teeth in jaws in broad patches (6–8 rows wide) of fine, pointed, hinged teeth, those in outer rows longer and sharper. Vomerine patch triangular, of fixed blunt (almost molariform) teeth. Teeth on palatine similar to those on vomer, and in an elongate patch about 4 or 5 rows broad.

Supramaxillary bone with ventral arm overlapping shallow notch in maxillary. Relationships of these two bones and their shapes are diagrammed in Fig. 2b.

Opercular spine well developed (longer than the pupil diameter), stout, and horizontally directed. The ethmoid (rostral) spine strongly developed, its ventral edge at about a 30° angle with the horizontal, the upper edge nearly horizontal and curved ventrally at its tip (Fig. 2a). Both spines normally imbedded in tissue.

Gas bladder in female (male unknown) a large sac occupying the upper portion of the body cavity to a point about halfway between verticals from the dorsal- and anal-fin origins. Sides of bladder with numerous blind outpocketings (Fig. 1).

Supratemporal canal with three pores, one one each side and one on the midline, opening from a posteriorly directed side canal. Lateral canal without pores (on head). Supraorbital canals with three pores, a shared median pore on posterior interorbit, a small pore above and slightly behind the anterior nostril and a large pore opening ventrally below and anteriorly to the anterior nostril in the subnasal pit. Infraorbital canal with six pores, the most anterior opening into the subnasal pit (below the anterior nostril), five slit-like openings along the rim that overhangs the upper jaw (the anterior two longest), and three in a vertical row behind the eye. Preoperculomandibular canals with 6 pores, none along its descending portion but with one pore at the interopercle-preopercle juncture, a second behind the angle of the jaw, three along the rami of the jaws (the anterior one enlarged), a fourth at the anterior corner of the jaw, and the last a large median pore on the chin shared by both systems.

Range.—*Raneya fluminensis* is still known only from the original collection "ESE da ilha Rasa". The depth of capture is unknown. Ilha Rasa is a small island in the Fernando de Naronha Archipelago and lies about at lat. 3°49′40″ S, long. 32°24′00″ W.

Discussion.—*Raneya fluminensis* possesses a more complete and regular squamation than any other species of Ophidiinae currently known. In some ways it approaches the Lepophidiinae but its overall form, its lack of pyloric caeca, and its modified gas bladder makes its placement in the Ophidiinae secure. Within this subfamily its relations are uncertain. The material is poor, and the male, which would be a better indicator of relations (especially in the structure of its gas bladder) is unknown or at least not available to me.

Paulo de Miranda Ribeiro (*in litt.*) informs me that he has designated No. 1890a as lectotype.

The large female contained large eggs. The ovary of the smaller female was also well developed, but the eggs were not much enlarged.

Brotuloides, gen. n.

Diagnosis.—A genus of the subfamily Lepophidiinae with which it shares: a regularly imbricate squamation (non anguilloid), a completely scaled nape, occiput, cheeck and opercles, a prominent forward projecting

ethomoid (rostral) spine, (absent in *Genypterus*), a general body form that tapers from a relatively robust head and forebody to a knife-like point at the tail, and the possession of pyloric caeca. Oral and branchial cavities, peritoneum, and entire digestive tract black. Rostral spine with vertically projecting basal component (Fig. 3a). Supramaxilla reduced, a simple plate, its posterior portion not curved downward; maxilla with a broad lateral ridge, its posterior margin somewhat concave (Fig. 3b). Pseudobranch reduced to a few long filaments. Vertical fins high, the combined lengths of opposing dorsal and anal rays greater than the body depth between their bases. Pectoral fins large, reaching level of anus, and with numerous (24–26) rays. Other features are included in the species account below.

Type of genus.—*Leptophidium emmelas* Gilbert, 1890.

Name.—Similar to *Brotula*, signifying the approach in body form of this genus to the nominal Brotulidae.

Brotuloides emmelas (Gilbert)

Figs. 3–5, Tables 1 and 2

Leptophidium emmelas Gilbert, 1890: 110 (description; type locality: coast of Lower California, at Albatross stations 3007 and 3008 in 362 and 306 fathoms). Böhlke, 1953:102 (list of syntypes at Stanford University).

Lepophidium emmelas, Jordan and Evermann, 1896:482 (compiled). Jordan and Evermann, 1898:2482–2483 (Comparison in key with related form; description compiled). Garman, 1899:142–143, pl. 73, fig. 3). (Description from new material; distribution; lateralis system illustrated). Cockerell, 1916:317–18 (description of scale structure; comparisons; "... perhaps *L. emmelas* should be generically separated ..."). Jordan, Evermann and Clark, 1930: 484 (compiled). Hildebrand and Barton, 1949:30 (tabular comparison with Pacific species of *Lepophidium*). Robins, 1959: 366 (name only).

Material examined.—USNM 44326 (1, 218; Lectotype) and SU 19216, 164–175; paratypes), Gulf of California, Lat. 25°27′30″ N, Long. 110°50′30″ W, 362 fms., ALBATROSS Station 3007, March 17, 1889. AMNH 3556 (1, 154), Gulf of California "Str. ALBATROSS". SIO 59–261 (7, 74–186) Mexico, Sinaloa, off Mazatlán, Lat. 22°44.0′ N, Long. 106°33.5′ W, 269 fms., May 9, 1959. SIO 59–266 (14, 118–211) Mexico, Sinaloa, off Río Elata, Lat. 23°55.0′ N, Long. 108°11.5′ W to Lat. 23°51.0′ N, Long. 18°07.5′ W, 395–405 fms., May 11, 1959. SIO 58–421 (1, 90) Gulf of Tehuantepec, Lat. 14°28′ N, Long. 93°09′ W to Lat. 14°27′ N, Long. 93°11′ W, 250 fms., Nov. 20, 1958. NYZS 25.444 (7, 127–175), Templeton Crocker Exped. Sta. 156-D-2,3; Lat. 23°13–15′ N, Long. 106°54–56′ W, 235 fms., April 28, 1956.

Description.—Frequency distributions of fin-ray and other counts, and measurements of body parts expressed as percentages of standard length are presented in Tables 1 and 2. In addition all specimens studied had 9 caudal rays (4 above and 5 below) and 7 branchiostegals. The arrangement of gill-rakers varies. There are either 4 or 5 rudiments on the upper limb and frequently one developed raker near the angle. On the lower limb, there are 7 to 10 (usually 8 or 9) developed rakers forming a graded series, the longest near the angle, the shortest anteriorly on the arch, preceded (on the anterior part of the lower limb) by 5 to 9 rudimentary rakers. The total count (18–22) is much higher than species of *Lepophidium* except for the one described below.

Compared with other ophidiids the bones of *B. emmelas* are poorly developed, many of them paper-thin, and the body is flabby. This character enhances its similarity to the deep-water brotulids and is perhaps responsible in part for the greater variation in measurements of body parts than one usually finds in the Ophidiidae; that is, the flaccid body makes precise measurements impossible. The body is deep forward but tapers very rapidly toward the tail (Fig. 5). The vertical fins are high; at any point behind the anus, the combined lengths of opposite dorsal and anal rays exceed the distance between their bases, usually by a considerable amount.

Pigmentation is fairly uniform, dusky throughout, becoming black in the region of opercles, the body cavity and the throat and chin. Juveniles are less dark than larger specimens. The fins are dark throughout, the pectorals black in adults. The lectotype has a suggestion of three dark areas in the posterior half of the dorsal fin (the last running onto the caudal) and two dark areas in the posterior half of the anal fin. But the type is otherwise faded. The oral and branchial chambers, the entire peritoneum and the en-

TABLE 1. FREQUENCY DISTRIBUTIONS OF VARIOUS COUNTS IN (A) *Brotuloides emmelas* (GILBERT) AND (B) *Lepophidium aporrhox, sp. n.*

	Dorsal Rays															
	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114
A.....	2	—	1	4	3	2	5	4	3	3*	2	2	—	1	1	—
B.....	—	—	—	—	—	—	—	—	—	—	1	—	—	3*	2	1

	Anal Rays																			
	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99
A.....	6*	3	4	5	6	2	—	1	3	1	—	—	1	—	—	—	—	—	—
B.....	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	4*	1	1

	Pectoral Rays						Gill Rakers					Pyloric Caeca					
	21	22	23	24	25	26	18	19	20	21	22	2	3	4	5	6	7
A.....	—	—	—	11	32*	15	3	5	12	9	7*	3	1	7*	8	1	1
B.....	1	7	6*	—	—	—	—	5*	1	1	—	—	—	5	2*	—	—

	Precaudal Vertebrae				Caudal Vertebrae				Total Vertebrae					
	13	14			42	43	44–52	53	55	56	57	58–65	66	
A.....	4	10*			1	12*	1 —	—	1	3	9*	1 —	—	
B.....	5*	—			—	—	— 4*	1	—	—	—	— 4*	1	

*A = Lectotype; B = Holotype.

tire digestive tract are black, except that the stomach may be pale in juveniles.

The body is entirely covered with small cycloid scales, nearly round but typically with the posterior field larger, the nucleus displaced anteriorly. The scales are thin and relatively deciduous, far more so than in species of *Lepophidium*. Nowhere is there any tendency for the scales to be imbedded, even in large specimens.

On the head the scales extend forward to the posterior part of the interorbit (about over the posterior border of the pupil). The opercles and cheeks are scaled, the scales reaching forward to a line from the hind border of the eye ventral to the posterior edge of the maxillary. The branchiostegal membranes, jaws, throat and anterior head are naked.

The anterior nostril is tubular, its rim highest posteriorly. The posterior nostril, the larger of the two, lies midway between the anterior nostril and the orbit. Its opening is vertically elongate, the anterior rim forming a flap that nearly covers the nostril.

Teeth are present in both jaws, and on the palatine and vomerine bones. The vomerine teeth are in a single row of about a dozen sharply pointed, fixed teeth restricted to the median portion of the anterior margin of the vomer. The patch is not a winged "V" as in *Lepophidium*. The palatine patch is long, and consists mainly of a single row of pointed fixed teeth, an occasional tooth out of line. Teeth in the jaws are more elongate, sharply pointed and hinged and are arranged in two irregular rows. The lips are not papillose, even in the larger specimens.

Fig. 3a depicts the shape and relationship of the supramaxillary and maxillary. A broad and rounded lateral ridge crosses the posterior portion of the maxillary. Posteriorly the maxillary is enlarged, and its hind border is shallowly concave. The supramaxillary is short and broad, a flat plate pointed in front and behind, that lies above and external to the upper surface of the maxillary.

An opercular spine is present and is horizontally oriented. The entire opercle is thin and the spine is easily bent and not promi-

TABLE 2. FREQUENCY DISTRIBUTIONS OF BODY MEASUREMENTS OF (A) *Brotuloides emmelas* (GILBERT) AND (B) *Lepophidium aporrhox, sp. n.* EXPRESSED AS PERCENTAGES OF STANDARD LENGTH
(* Indicates Lectotype and Holotype for A and B, Respectively)

	Head Length									Predorsal Distance				Snout Tip to Occiput							Snout Length	
	21	22	23	24	25	26	27	28	29	26	27	28	29	14	15	16	17	18	19	20	4	5
A	—	—	—	—	—	5*	6	2	1	6	2	5*	1	—	—	—	8*	5	—	1	6	8*
B	1	4*	1	1	—	—	—	—	—	2	3*	2	—	5*	2	—	—	—	—	—	4	3*

	Preanal (Fin) Distance														Postorbital Length								
	33	34	35	36	37	38	39	40	41	42	43	44	45	46	10	11	12	13	14	15	16	17	
A	—	—	—	—	—	—	—	1	1	2	4	4*	1	1	—	—	—	—	—	6	6	2*	
B	1	1	—	1	3	—	1*	—	—	—	—	—	—	—	1	4	1*	1	—	—	—	—	

	Body Depth[1] (1)							Body Depth[1] (2)							Body Depth[1] (3)							
	12	13	14	15	16	17	18	14	15	16	17	18	19	20	11	12	13	14	15	16	17	
A	—	—	—	5	4*	1	1	—	—	6	3*	2	—	2	1	6*	1	3	—	2	1	
B	1	4	2*	—	—	—	—	3	1*	2	—	—	—	—	—	2	1	2	2*	—	—	

	Pectoral-Fin Length							Pelvic-Fin Length													Maxillary Length		
								Outer Ray							Inner Ray								
	11	12	13	14	15	16	17	10	11	12	13	14	15	16	6	7	8	9	10	11	10	11	12
A	—	1*	—	3	4	5	1	1	3	6*	4	—	—	—	2*	8	4	—	—	—	—	6	8*
B	5*	2	—	—	—	—	—	—	—	—	—	2	3*	2	—	—	—	—	4*	3	6*	1	—

	Orbit Diameter			Bony Interorbit			Caudal-Fin Length				Length of Lateral Line[1]									
	6	7	8	2	3	4	6	7	8	9	80	81	82	83	84	85	86	87	88	89
A	4*	9	1	1	12*	—	—	—	9*	4	1	—	1	3*	—	—	2	—	1	—
B	—	7*	—	—	4	3*	3*	4	—	—	—	—	—	—	1	1	—	1	—	2*

[1] Body depth is measured at: (1) occiput, (2) dorsal-fin origin, (3) anal-fin origin. Lateral-line length is measured from the snout tip to the posteri or end of the lateral line.

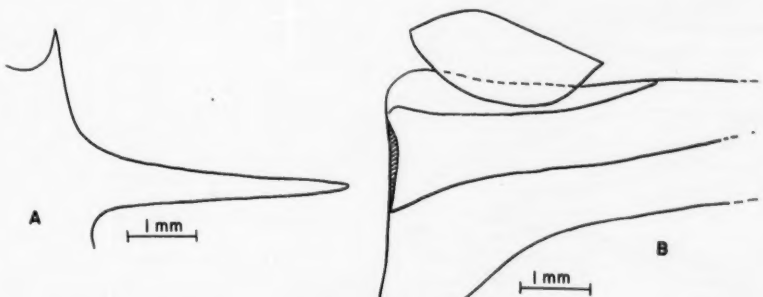

Fig. 3. Lateral view of (a) ethmoid spine and (b) maxillary and supramaxillary bones of *Brotuloides emmelas* (Gilbert). A composite drawing but based largely on a specimen from SIO 59–266 (see text for details).

nent. The preopercular margin is not free. Fig. 3a shows the ethmoid or rostral spine. Its anterior component is horizontally oriented, never curved. The dorsally projecting basal component is diagnostic. Also, a strong spine projects laterally from the parethmoid-prefrontal area. This spine is easily detected just behind the posterior nostril.

The gas bladder is a large, relatively thin-walled sac, rounded behind and reaching to a point about midway between the levels of the dorsal-fin origin and the anus. No sexual dimorphism in the gas bladder was noted.

The pyloric caeca are short and rounded and in the most common arrangement there are 3 or 4 ventrally and one dorsally. All are arranged in a single whorl; that is, none is placed anteriorly to another.

The weak bone structure, flaccid tissue and dark pigment makes it especially difficult to trace the laterialis system in *B. emmelas*. The supratemporal canal differs from all known species of *Lepophidium* in having 4 instead of 3 pores, one laterally (on each side) near the canal's juncture with the lateral canal, and a pair of central pores, one on either side of the mid-dorsal line. The lateral canal has but one pore, that just anterior to the dorsal attachment of the gill membrane to the head. Nine pores are in each preoperculomandibular canal, 3 on its descending portion, the third at the lower border of the preopercle and the remaining 6 along the lower jaw, arranged as shown in Fig. 4. There are 8 pores on the infraorbital canal, 3 on its descending arm, the third also the first in the horizontal arm that extends along the suborbital rim that overhangs the upper jaw. The final pore in the infraorbital canal is in the subnasal pit. Each supraorbital canal contains one pore well above the posterior quadrant of the eye on the frontal region, the second a shared median interorbital pore, the third above the anterior nostril and the fourth in the subnasal pit below the anterior nostril. This arrangement may be compared with the account by Garman (1899:361, pl. 73, figure 3) of the neural disks. No variation was noted in numbers of pores and there is no apparent relationship in the placement of the pores and disks in the canal system.

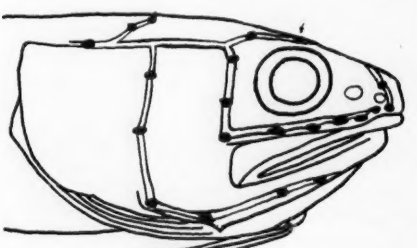

Fig. 4. Lateralis system of *Brotuloides emmelas* (Gilbert). A composite drawing; pores indicated by darkened circles, nostrils by open circles; lateral view above, ventral view below.

Range and habitat.—*Brotuloides emmelas* is known along the Pacific coast of North America from the southern portion of the Gulf of California (*ca.* 25°27′) to the southern portion of the Gulf of Tehuantepec (*ca.* 14°27–28′ N). The known depth distribution for this bottom-dwelling species is from 300–405 fathoms in the Gulf of California and 235 to 269 fathoms off Mazatlán, and 250 fathoms in the Gulf of Tehuantepec. Green mud is the most frequent description of bottom type in these areas.

Discussion.—*Brotuloides emmelas* is clearly to be associated with *Lepophidium* within the subfamily Lepophidiinae. Many of its distinctive features (*e.g.*, the weak bone structure, the flabby body) are ones generally associated with life in deep waters. Its depth distribution is deeper than any species of *Lepophidium* although the recently described *L. kallion* is now known to occur to 260 fathoms and it shows no tendency toward *Brotuloides* in its characteristics. That *emmelas* should be placed separately is not a new suggestion. Cockerell (1916:318) made such a suggestion without proposing a name. More recently Robert R. Rofen reached this conclusion in unpublished findings.

Lepophidium aporrhox sp. n.

Figures 5–6, Tables 1 and 2

Material examined.—Holotype: USNM 195853, an adult male, 161 mm. in standard length, Lat. 07°18′ N, Long. 54°08′ W, 50 fathoms, M/V OREGON station 2016, November 8, 1957. Paratypes: CNHM 64503

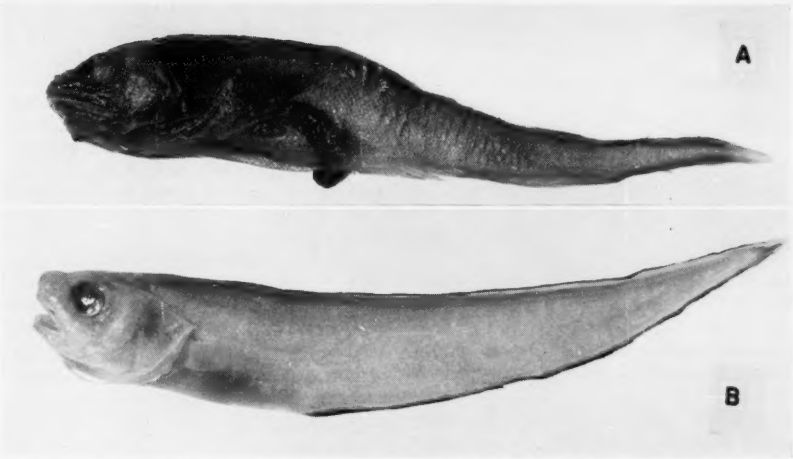

Fig. 5. a: Lateral view of *Brotuloides emmelas* (Gilbert), SIO 59–266, an adult female, 174 mm. in standard length. b: Lateral view of holotype of *Lepophidium aporrhox*, USNM 195853, and adult male, 161 mm. in standard length.

(1, 132) and UMML 2302 (1, 113) both taken with the holotype. USNM 195853 (1, 96), Lat. 16°23′ N, Long. 83°20′ W, 55 fathoms, M/V OREGON station 1864, August 21, 1957. CNHM 64510 (3, 98–148), Lat. 08°32′ N, 59°05′ W, 28–33 fathoms, M/V OREGON station 2226, August 28, 1958.

Diagnosis.—A small stocky species of *Lepophidium* of rather uniform pigmentation except for the black margin of the dorsal and anal fins. Dorsal and anal rays few, 109–114 and 96–99 respectively. Precaudal vertebrae 13, caudal vertebrae 52–53, total 65–66. Gillrakers numerous, 19–21, with a rudimentary raker between each developed raker on the lower limb. Peritoneum silvery, hindgut pale, esophagus black, gill chamber and pharynx dark, gill bar sooty, anterior part of oral cavity pale.

Description.—Frequency distributions of fin ray and other counts and measurements of body parts expressed as percentages of standard length are presented in Tables 1 and 2. All specimens have 9 caudal rays (4 above, 5 below) and those checked had 7 branchiostegal rays. The arrangement of gillrakers is unique in the genus. Usually there are rudiments on the upper limb (one had 4, and one had 2 rudiments plus 1 developed raker). The first 11 elements on the lower limb alternate between developed and rudimentary elements and the anterior 5 elements are rudimentary. The total of 19 to 21 rakers is the highest known in the genus *Lepophidium*.

Pigmentation is rather uniform. The body is pale brown, almost straw-colored in preservative, and darker dorsally than below. There are no spots, bars or blotches. The snout tip, and the anterior portion of the lower jaw are covered with large melanophores. The maxillary is unmarked. Indeed, the only noteworthy feature of external color pattern in *L. apporhox* is the continuous black margin to the dorsal and anal fins. The dark anal-fin margin is broader than that in the dorsal fin. The caudal fin is dusky at its base, this mark extending onto the tail as a dark wedge or "V" (see Fig. 5b). The dark margins of the dorsal and anal fins extend onto the caudal fin but are not continuous around it; that is, the caudal tip is pale. Internally, the peritoneum is silvery, the hindgut and stomach pale, the esophagus black, the gill chamber (especially anteriorly) and posterior part of the mouth black, the gill bar sooty and the anterior part of the mouth pale, sometimes streaked with dusky.

Teeth are present on both jaws and on the palatines and the vomer. Those in the jaws are relatively short but hinged and pointed (as in related species) and in 4 or 5 rows above, and 3 to 5 rows below. The dentary patch is widest at the symphysis. The vomerine and palatine teeth are small but short, blunt, and molariform. Those on

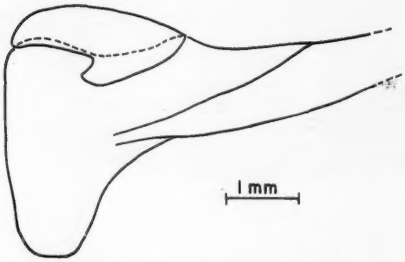

Fig. 6. Lateral view of maxillary and supera-maxillary of holotype of *Lepophidium aporrhox*.

the vomer are in one row, those on the palatines form a patch generally 2, irregularly 3, rows wide.

The rostral spine reaches to the snout tip, and generally is the most anterior point on the specimen. The snout itself is squarish but not prominent and the mouth, while definitely inferior, is not so decidedly included as in many other species of *Lepophidium*. The opercle ends in a flattened spine that is not prominent. Fig. 6 shows the supermaxillary and the posterior end of the maxillary. The ventral edge of the supramaxillary is curved and has a pronounced, caudally projecting, ventral process.

The anterior tip of the lower jaw is enlarged forming a bulge above (on the tooth patch) and below. This enlarged area fits into a recess at the juncture of the premaxillaries above. The upper jaw is thus notched anteriorly.

Development of the lateralis system on the head is essentially the same as that described for *L. pheromystax* (Robins, 1960:87, Fig. 2) and this system is therefore not illustrated for *aporrhox*. The pores are as follows: lateral canal—1, supratemporal canal—3, supraorbital canal—4, infraorbital canal—8, preoperculomandibular canal—8. The anterior nostril opens through a short tube; the posterior nostril is large, oval and lacks a tube.

Name.—From the Greek, *aporrhox*, meaning broken off, in allusion to the stocky proportions of this species.

Range.—*L. aporrhox* is distributed along the Atlantic coast of northern South America from Surinam to eastern Venezuela and in the western Caribbean north of eastern Honduras. Its known bathymetric distribution is from 28 to 55 fathoms. This species may be expected through the southern Caribbean wherever suitable bottom occurs within the approximate depth limits listed above.

Discussion.—The stocky proportions, peculiar arrangement of gillrakers and low numbers of dorsal and anal fin rays and of vertebrae place *aporrhox* well aside from other described species of *Lepophidium*. In addition to these features, *L. pheromystax* which occurs through the same general region and depths as *aporrhox*, is easily identified by its spotted color pattern (Robins, 1960: Fig. 1b, c).

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THE MARINE LABORATORY, UNIVERSITY OF MIAMI

Herpetological Notes

THE STATUS OF *TYPHLOPS SILUS* LEGLER.—*Typhlops silus* Legler (1959, *Herpetologica 15:105–112*) differs from *lumbricalis* in two characters: (a) the deepened sulci of the rostral and nasal scales, giving a trilobate profile when viewed from above, and (b) a paler, less contrasting color. In all other features of scutellation—number of scale rows, shape and arrangement of head scales—it is indistinguishable from the "sympatric" *lumbricalis*. The type and two paratypes of *silus* are smaller than mature *lumbricalis* but nothing is known of their maturity; it is conceivable that they could be young of a larger species.

In *Typhlops*, individuals about to shed are characterized by a dulling of patterns, if one is present, by a gray coloration during some stage of the process, and by the eyes becoming less visible. Associated with these changes, the scales on the head appear inflated and the sutures between them become more prominent. Of the *Typhlops* available, three species had both normal and preshedding individuals represented. A total of 27 specimens representing these three species were studied; the results are shown in Table 1. The seven specimens that are gray in color obviously are about to shed and all show the exaggerated sulci between the head scales, giving the head a trilobate appearance when viewed from above. The remaining twenty specimens are of normal coloration and have smooth, round profiles.

The characters that distinguish *silus* from *lumbricalis* are also the same characters shown by *lumbricalis* and other species of *Typhlops* just prior to ecdysis. *Typhlops silus* evidently

TABLE 1

Name		Color	Profile from above
T. lumbricalis			
CM 32575	Bimini	Brown	Round, smooth
" 32576	"	Pale gray	Trilobate
AMNH 77795	Cuba	" "	"
" 77797	"	" "	"
" 78584	"	" "	"
" 77793–94	"	Brown	Round, smooth
" 77796	"	"	" "
" 77798–77809	"	"	" "
KU 47470	" (Paratype of *T. silus*)	Pale gray	Trilobate
" 47471	" " " " "	Gray brown	"
T. jamaicensis			
CM 33374	Jamaica	Pale gray	Extremely trilobate
" 33375	"	Brown	Round, smooth
T. braminus			
CM 2635a	Philippine Islands	Gray	Slightly trilobate
" 2635b	" "	"	" "
" 2635c	" "	Brown	Round, smooth
" 2635d	" "	"	" "
" 2635e	" "	"	" "

is based on preshedding individuals of *T. lumbricalis* and is a synonym of *T. lumbricalis*.

Legler also discusses a specimen from Puerto Rico that resembles *rostellatus* of that island except for its color ("body pale gray") and its trilobate snout. The color indicates that this specimen also was about to shed and is presumably *rostellatus*.

The type of *T. sulcatus* probably is a specimen about to shed, though I have not examined it. However its condition does not affect the validity of Cope's name. As Legler pointed out, the high number of dorsal scales separates that form from others in the area.

This still leaves unresolved the question of why Cuba, the largest island in the Caribbean has only one species of *Typhlops*, a situation even more remarkable when one considers that in the northern Bahamas, with obvious faunal affinities with Cuba, there are two species of *Typhlops, lumbricalis* and *biminiensis*.

One of 11 specimens of *lumbricalis* from Pinar del Rio, Cuba (AMNH 77797) is remarkable in that it lacks supraoculars, their place being occupied by a dorsal extension of the preoculars which contact both the first mid-dorsal scale and the parietal. The other ten from there are normal *lumbricalis*.

Specimens studied are deposited in the following institutions: Carnegie Museum (CM); University of Kansas Museum of Natural History (KU) and the American Museum of Natural History (AMNH). I am grateful to Charles Bogert and William Duellman for permission to borrow specimens in their care.—Neil D. Richmond, *Carnegie Museum, Pittsburgh, Pennsylvania.*

VARIATIONS IN CONCENTRATIONS OF A METACHROMATIC STAINING ANTICOAGULANT IN PLASMA OF THE TURTLE, *PSEUDEMYS SCRIPTA ELEGANS*.—According to Jacques *et al* (1959, *Physiologist 2:61*) turtle plasma contains an anticoagulant substance which has the metachromatic staining properties of a mucopolysaccharide. The present study was undertaken to determine the yield of metachromatic staining anticoagulant in cold exposed turtles and, further, to examine the efficacy of trypsin digestion and incubation in improving the yield of this substance. The latter interest was prompted by the fact that the mucopolysaccharide, heparin, reacts with proteins to form salts (Fisher, 1935, *Biochem. Zeit. 278:133*; Jacques, 1935, *Biochem. J. 37:189*; Jaques and Bell, 1954, *Methods of Biochem. Anal. 7:257*). Furthermore, Engleberg, *et al* (1955, *J. Lab. Clin. Med. 46:653*) have indicated that native circulating heparin is strongly protein bound and suggest the use of proteolytic enzymes to split the heparin-protein complex.

Materials and Methods.—Female specimens of the red-eared turtle, *Pseudemys scripta elegans*, with an average weight of 853 ± 20 g were used. A control or "warm" group was maintained at 21–22°C. (average, 102 days) and an experimental or "cold torpid" group was maintained at 2–4°C. (average, 92 days). All animals were placed in polyethylene containers with water to a depth of 4 cm and kept in their respective environment, without food, from one to 6 months. The animals were sacrificed during the months of October through January. Ventricular blood was obtained by the method described by Musacchia and Sievers (1956, *Am. J. Physiol. 187:99*).

Three ml of ventricular blood were placed in a test tube containing 1.5 ml of 1.46% sodium citrate (Kaplan, 1956, *Herpetologica 12:269*) and centrifuged at 1500 r.p.m. for 10 minutes. The supernatant was pipetted into a 25 ml graduated test tube, the precipitate washed with 2 ml of 0.7% sodium chloride and centrifuged at 1500 r.p.m. for 10 minutes. The wash was added to the supernatant and the volume adjusted to 6 ml, with 0.7% sodium chloride.

A modification of the Bassiouni method (1953, *J. Clin. Path. 6:39*; Jacques, Dissertation, 1960, St. Louis University Library, St. Louis, Mo.) for quantitative determination of heparin and "heparin-like" substances eg. chondroitin sulfates A and B was used for extraction and assay of the metachromatic staining substance from turtle blood.

The efficacy of partial hydrolysis of the plasma proteins by tryptic digestion and incubation was ascertained prior to extraction. Trypsin was used in the form of a Purified Trypsin Concentrate (PTC) containing 80 mg/ml in 50% glycerol. The most effective trypsin concentration and hydrolysis conditions were found to be 0.05 ml PTC/6 ml plasma, pH 8–9, and incubation at 37°C for 15 hours.

Results.—A greater yield of anticoagulant substance was obtained from cold torpid animal plasma than from plasma obtained from warm animals (Table 1). The yield of the metachromatic staining anticoagulant was higher from plasma incubated with 0.05 ml PTC solution than in plasma incubated without PTC, or plasma incubated with concentrations of PTC greater than 0.05 ml. The plasma from warm animals, when incubated and trypsin hydrolyzed, yielded an increased amount of the metachromatic staining anticoagulant (.057 mg/2 ml plasma as compared with .037 and .041 mg/2 ml plasma under other analytical conditions). On the other hand, similar treatment of plasma from cold torpid animals did

TABLE 1. METACHROMATIC STAINING ANTICOAGULANT EXTRACTED BY VARIOUS PROCEDURES FROM TURTLE (*Pseudemys scripta elegans*) PLASMA

Animals*	Analytical Conditions		Metachromatic Substance (mg./2 ml. Plasma)	Student "t" value**
	Incubation (37°C)	Trypsin Added		
15 warm	no	no	.041 ± .03	6.06
19 cold	"	"	.164 ± .08	
16 warm	yes	"	.037 ± .02	6.70
19 cold	"	"	.165 ± .08	
17 warm	"	yes	.057 ± .03	7.78
19 cold	"	"	.166 ± .10	

* Body temperatures: warm = 21–22° C.; cold = 2–4° C.
** $t(P = 0.001) = 3.29$

not result in enhanced yields. The results are summarized in Table 1.

Discussion.—Relatively few characteristics of hematology and blood circulation in cold torpid ("hibernating") turtles have been studied. Musacchia and Sievers (1956, *Am. J. Physiol. 187:99*) observed that, within the body cavity of *Chrysemys picta* maintained at 0°C and lower, body fluids often froze. In these animals cardiac activity was considerably reduced but recovery could be elicited. These observations and others, relating to reduced cardiac and circulatory function during cold torpor (Musacchia, unpublished), led to the view that any mechanism or physiological alteration which prevents hemostasis may be an advantageous feature during hibernal over-wintering. The role of a naturally occurring anticoagulant would be favorable, for example, in the prevention of clots, thrombi, etc. in cold torpid turtles. Thus the present observation of an increased concentration of metachromatic staining anticoagulant in blood of cold torpid *Pseudemys scripta elegans* is viewed as a physiological adjustment which assists the turtle in maintaining hemofluidity during periods of prolonged cold torpor, viz., hibernation.

The increased yield of metachromatic staining anticoagulant from warm animal plasma as the result of incubation and trypsin hydrolysis, suggests breakdown of a protein complex. A comparison of the disproportion in yields obtained from plasma from warm as opposed to cold torpid groups, however, raises doubt that the anticoagulant substance is present primarily as an anticoagulant-protein complex in the circulating blood of these animals. It is possible that anticoagulant activity of the substance is inhibited when bound with protein. During the initial cold acclimatization, a quantity of the anticoagulant substance may be released from the anticoagulant-protein complex to maintain hemofluidity. This could possibly explain the somewhat higher yield of metachromatic staining anticoagulant obtained by tryptic hydrolysis of the warm animal plasma. The role of this anticoagulant substance in circulation during hibernation and its chemical properties are under investigation.

A part of this investigation was carried out during the tenure of a Postdoctoral Fellowship from the National Heart Institute, United States Public Health Service.—F. A. Jacques[1] and X. J. Musacchia, *Department of Biology, Saint Louis University and Laboratories of Cardinal Glennon Memorial Hospital, St. Louis, Missouri.*

[1] NHI, Postdoctoral Fellow

THE RUNNING SPEEDS OF THE LIZARDS *DIPSOSAURUS DORSALIS* AND *CALLISAURUS DRACONOIDES*.—My observations were made in April, 1955, and in August, 1958, between Thousand Palms and Cathedral City, Riverside County, California, where *Dipsosaurus dorsalis* and *Callisaurus draconoides* could be found among open dunes (mean distance between *Larrea* bushes about 40 feet) on sand fine enough for tracking.

It was found necessary to time previously undisturbed animals; captives, whether released seconds after noosing or given several hours rest, proved to be consistently slower. Each record of speed was obtained by approaching a lizard without apparently alarming it, then chasing it until it was lost to sight or took shelter. A stopwatch was started as the lizard passed one point, and stopped as it passed another. In most cases the watch was stopped as soon as the lizard began to slow before reaching cover. To determine the distance run, a tape was laid along the line of tracks left by the lizard between the two points. Whenever possible, the animal was shot immediately and its cloacal temperature measured with a Schultheis Museum Special thermometer.

Twenty-three adult *Dipsosaurus* averaged 7.28 meters per second, with a standard deviation of 0.680; distances run ranged from 7.6 to 41.1 m. The fastest individual ran 41.1 m. in 4.8 sec. Juveniles were slower than adults and seldom ran far enough to yield an accurate estimate. The best record for a juvenile (snout to vent length, 4.5 cm.) was 9.4 m. in 1.6 sec.; this was slower than any adult tested.

Speeds of seven adult *Callisaurus* averaged 7.19 m.p.s.; distances run ranged from 9.1 to 20.4 m. The fastest individual ran 14.6 m. in 1.5 sec. Both *Callisaurus* and *Dipsosaurus* ran bipedally.

Since errors in the measurement of distance

were relatively negligible, the accuracy of an estimate of speed depends on the accuracy of the timing method. In laboratory simulations of my techniques, the maximum error was found to be 0.3 seconds, and to be independent of the time elapsed during a run. With maximum timing error added to the elapsed time in the best record for each species, the highest speeds observed become at least 8.06 m.p.s. (18.0 miles per hour) for *Dipsosaurus* and at least 8.11 m.p.s. (18.1 miles per hour) for *Callisaurus*. Since the error in each speed measurement is inversely proportional to elapsed time, application of this method is estimating the speeds of animals which run in short dashes is precluded.

The profound influence of body temperature on motor ability makes it important to know the former in evaluating motor performance in ectotherms. *Dipsosaurus* and *Callisaurus* normally are active only within a narrow range of body temperatures (Cowles and Bogert, 1944, *Bull. Amer. Mus. Nat. Hist. 83:265–96*). Although the cloacal temperature of the fastest *Dipsosaurus* was not obtained, there is no reason to suspect that it was not within the range 39° to 44° C. found for 20 other adults under similar conditions in this study. The cloacal temperature of the fastest *Callisaurus* was 40.2° C.

The speeds reported here may not represent the maximum capabilities of the species concerned. Since man probably has never been an important factor in the behavioral evolution of these lizards, their reaction to human pursuit may not be the equivalent of their reaction to pursuit by more usual predators.—DANIEL A. BELKIN, *Department of Biology, University of Florida, Gainesville.*

Ichthyological Notes

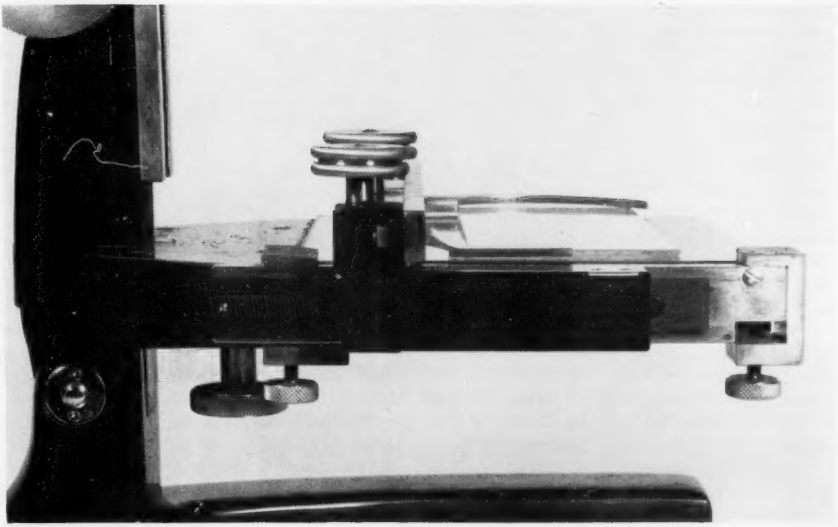
A DEVICE FOR MEASURING LARVAL AND JUVENILE FISHES.—Many methods are used to measure larval, postlarval and juvenile fishes and usually require the use of ocular micrometers, dividers, calipers or dial calipers. In the case of cleared and stained fish, specimens are sometimes laid on a transparent plastic ruler and measurements read by transmitted light. All of these are time consuming and subject to inaccuracies.

During studies of early development of several fishes, a method of measuring larvae and juveniles which made use of a graduated mechanical stage was devised. By the use of this method accurate body measurements can be made to one tenth of a millimeter on fish ranging in size from the smallest larva to a maximum standard length of 107 mm. No change in calibration is required with change in magnification as is necessary when using an ocular micrometer. Furthermore, the inherent inaccuracy of other methods, caused by relocating reference points after each measurement, is eliminated.

Materials.—Graduated mechanical stages are made primarily for compound research microscopes. They generally accommodate slides too short for use with specimens much longer than about 55 mm. A Breed mechanical stage (designed for making bacterial counts in milk) was finally selected as suitable for the purpose. This stage accommodates a sufficiently large standard slide (115 × 52 mm.) and is graduated in millimeters. Measurements can be read to tenths of a millimeter on a vernier scale.

Only one modification is needed on the mechanical stage. The original clamps, manufactured for the comparatively thin stage of a compound microscope, must be changed to suit the thicker stage of the dissecting microscope. New brass clamps, opening to 17.5 mm., were built (Fig. 1). The only necessary modification of the microscope is placement of a cross-hair disc in one of the oculars. Although the Breed 115 mm. standard slide is quite large, it was necessary to cut new slides to a length of 127 mm. in order to allow some excess space beyond the snout of the specimens when the stage was set at zero and the cross hair set at the tip of the snout. Aligning the specimen may be facilitated by etching or scribing a 5 mm. grid on the slide.

Methods.—To take a set of measurements, such as snout length, eye diameter, head length, snout to ventral fin, etc., the stage is first set at zero. The fish is placed on the slide, which is locked in the mechanical stage (Fig. 2). The microscope is focused on the snout and the fish moved to the zero position; i.e., the tip of the snout touches the center of the cross hairs in the field. At each point to be measured the microscope should be refocused because it may not be in the same plane as the previous point. The scale should be returned to zero to recheck the snout position before removing the fish. Often an array of measure-



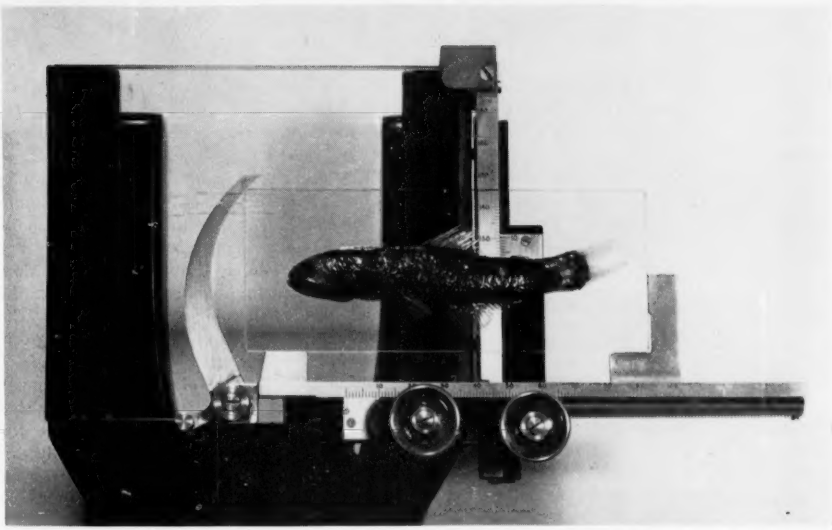


Fig. 1. Breed mechanical stage adopted to thick microscope stage in order to measure larval and juvenile fishes.
Fig. 2. Specimen on slide (microscope head removed) and scale set at zero to show the method of measuring a small fish.

ments, e.g., snout length, head length, snout to dorsal, snout to anus, and standard length, can be taken rapidly from one zero setting with zero set at the snout. Subtractive procedures are necessary only where some particular measurement, such as eye diameter, is an interrupted part of a whole. Depths can be measured at pectoral, at caudal peduncle, etc. with the vertical scale.

In the case of a cleared and stained fish the specimen can be moved along smoothly to count vertebrae and fin rays. When measuring fish having a slight curl, the specimen may be pinned to a layer of cork glued on the slide.

Acknowledgments.—I wish to take this opportunity to thank Mr. Raymond M. Blei of the Special Developments section at Scripps Institu-

tion of Oceanography for machining the new stage clamps.—ROBERT C. COUNTS, *Biological Laboratory, U. S. Bureau of Commercial Fisheries, La Jolla, California. Published by permission of the Director, U. S. Bureal of Commercial Fisheries, Washington, D. C.*

BANDED COLOR PHASES OF TWO PELAGIC FISHES, *CORYPHAENA HIPPURUS* AND *KATSUWONUS PELAMIS*.—Banded color patterns in juveniles of pelagic fish species which do not, as adults, generally exhibit such patterns, have been recorded in the past, although not particularly commented upon. Observations of the last few years suggest that such patterns may also be common in the adults, but only while they are alive. Specifically, we wish to document the existence of banded color phases in living dolphin, *Coryphaena hippurus* Linnaeus 1758, and oceanic skipjack *Katsuwonus pelamis* (Linnaeus 1758).

One of us (Marr) observed banded dolphin off the west coast of Central America in the course of studies of the tropical tunas. An entry from his field notes for 17 March 1947 is: "At 0715 a small flock of boobies was seen working a school of bait. Upon approaching we could see a small school of bait. Larger fish breaking the surface slightly appeared to be dolphin (judging from their shape) but were banded; black bands alternating with greenish yellow ones! The bands were approximately 2" wide."

An entry of 11 April 1947 is: "At 0750 we came on a school of spinners [a species of porpoise] and yellowfin ... We caught 252 yellowfin and three dolphin. One of the latter presented, while in the water, the same banded appearance previously noted. This was not discernible after the fish was brought aboard."

Both of these observations were made in the general area off Puntarenas, Costa Rica.

Two references to this phenomenon have been encountered in perhaps unconventional sources. One (Lamb and Cleveland, 1938. *Enchanted Vagabonds, p. 142*) relates to observations made in the general vicinity of Acapulco, Mexico: "Dolphins, to us, are the most beautiful fish in the sea. Their streamlined bodies are swift and graceful. They have a chameleon-like ability to change their color, turning from green to blue or brown, to yellow and brown stripes, their fighting colors."

The other (Hemingway, 1952. *The Old Man and the Sea, p. 79.*) refers to events in another ocean:

"I would like to fly very slowly at two hundred fathoms high and see the fish from above. In the turtle boats I was in the cross-trees of the mast-head and even at that height I saw much. The dolphin looked greener from there and you can see their stripes and their purple spots and you can see all of the school as they swim. Why is it that all the fast-moving fish of the dark current have purple backs and usually purple stripes or spots? The dolphin looks green of course because he is really golden. But when he comes to feed, truly hungry, purple stripes show in his sides as on a marlin. Can it be anger, or the greater speed he makes that brings them out?"

The other of us (Strasburg) has more recently had the opportunity to confirm the existence of this banded color phase in adult dolphin, and to extend our knowledge of its existence to adult oceanic skipjack. Observations of both species were made from an underwater viewing chamber, which has been described by Strasburg and Yuen (*J. Cons. Int. Explor. Mer*, In Press). This chamber is located near the stern of the U. S. Bureau of Commercial Fisheries' research vessel *Charles H. Gilbert*, and from it studies are being made of the feeding and schooling habits of pelagic fishes, principally Hawaiian skipjack. Motion pictures, still pictures and voice recordings provide the basis for subsequent analysis and also for the following account.

In July 1959, two large floating logs were encountered in Hawaiian waters, one a short distance off Waianae, Oahu, the other about 150 miles north of Nihoa. These logs were covered with sessile marine life and were closely accompanied by schools of small fish. Swimming around the logs were dolphin in surprisingly large numbers, 65 and 57 of which were ultimately landed after chumming with live bait. The length range of the captured dolphin was 620–1005 mm. More impressive than the number of dolphin was the variability of their color and color pattern. The ground color of various individuals was green, yellow, or silver, overlain with vertical bands or bars ranging from dark olive to black. In many individuals the bars were restricted to the head and trunk, the tail being the same color as the bars. In other fish, barring was uniformly distributed over the entire body, or sometimes completely lacking. A dolphin with at least three bars is shown in Fig. 1. Although difficult to detect from the photograph, the more anterior bars extend onto the dorsal fin membranes.

As noted above, the main use of the subsurface viewing chamber was for studying skipjack behavior, particularly their behavior during feeding. At such times large schools of skipjack were attracted to the ship's stern with live bait. Fig. 2 depicts a portion of such a school, and it is immediately apparent that skipjack, too, bear vertical bars. Bars were seen on fish weighing from 2 to over 30 pounds, but they were not always

Fig. 1. Banded color phase of the dolphin, *Coryphaena hippurus*.

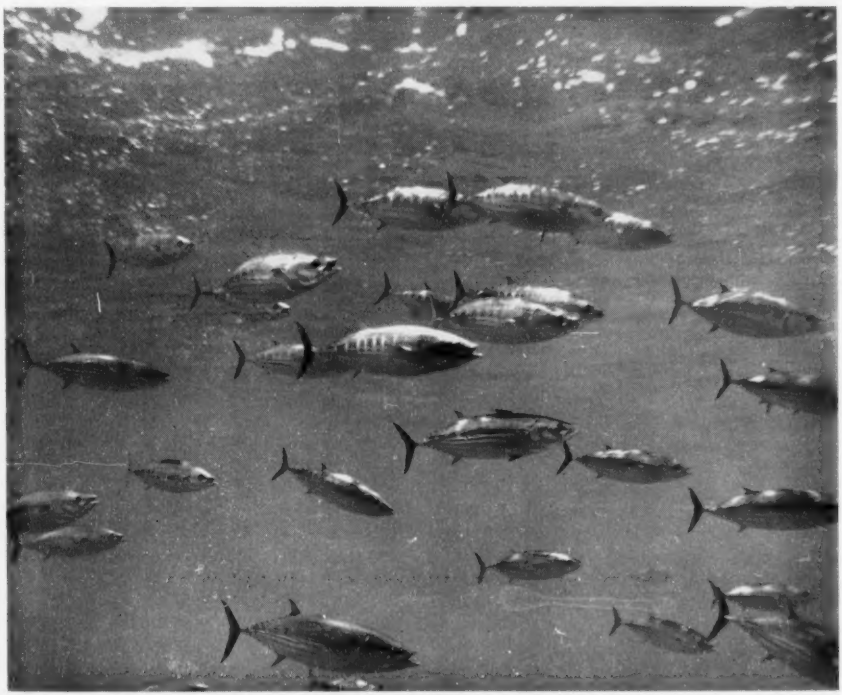


Fig. 2. School of oceanic skipjack, *Katsuwonus pelamis*, showing both vertical bars and horizontal stripes.

observed on all members of a school. The effect of the viewing angle on the visibility of the bars is not known, but it is apparent that the presence or absence of the bars was under nervous control. Hooked fish bore the marks only briefly after leaving the water and lost all vestiges of them when moribund.

It is apparent (see Fig. 2) that the persistent, dark horizontal stripes are interrupted by light vertical bars, while the light horizontal stripes are

not interrupted by dark vertical bars. The transitory barred or banded appearance, then, is produced by light rather than dark bars. Presumably this is accomplished by the contraction of melanophores.

In addition to Hawaii, underwater observations were made of bars on skipjack in the Line Islands and off the west coast of Central America. It is likely that these marks are a regularly occurring feature which has not been recorded in photographs or paintings because of their evanescent nature and the general lack of underwater viewing facilities.

A cursory search of the literature and available photographs reveals that vertical bars are common among pelagic fishes. In addition to the ephemeral bands of adult *Coryphaena* and *Katsuwonus*, we note more or less permanent bars or bar-like rows of spots on adult *Neothunnus, Acanthocybium, Istiophorus, Makaira, Naucrates,* and *Ranzania,* and on juvenile *Coryphaena* and *Neothunnus,* among the more conspicuous pelagic forms. Because of the similarity in ecological position of most of these fishes, it is tempting to postulate an adaptive importance for the bars. To the submerged human eye they render the fish neither more nor less conspicuous, for the marks are only visible at short range, long after the fish has come into view. (When viewed from above the surface of the water they do, however, have the effect of presenting an unfamiliar pattern on a familiar silhouette, thus making sight identifications difficult). Whether bars have a communicative function between fish is a question to be answered only after more detailed observations than we have been able to make.—DONALD W. STRASBURG and JOHN C. MARR, *U. S. Bureau of Commercial Fisheries, Honolulu, Hawaii.*

RECAPTURES OF TAGGED SPINY DOGFISH, *SQUALUS ACANTHIAS.*—The migratory nature of the spiny dogfish, *Squalus acanthias* Linnaeus, is well known to fishery biologists. The seasonal migrations in the Northwest Atlantic have been described by Templeman (1944, *Res. Bull. Div. Fish. Resour. Newfoundland (15):1–102*) and Bigelow and Schroeder (1953, *Fish. Bull. U. S. Fish and Wildl. Serv. 53(74):47–51*). These authors suggested there is a general movement northward in the spring and early summer, and a general movement southward in the autumn. Bigelow and Schroeder (*op. cit.*) also reported that it now seems certain that spiny dogfish overwinter chiefly in the deeper water offshore. This suggests the possibility of an inshore-offshore migration.

Spiny dogfish have been tagged at sea whenever feasible during our research cruises. This note is a progress report of the dogfish recoveries to date.

TABLE 1.—RETURNS OF TAGGED SPINY DOGFISH, *Squalus acanthias.*

Date and locality of		Weeks at liberty	Distance (miles)
Tagging	Recapture		
July 7, 1956 Boon Island, Me. (43°05′N–70°28′W)	July 22, 1957 Cape Ann, Mass. (42°44′N–70°19′W)	54	22
July 7, 1956 Boon Island, Me. (43°05′N–70°28′W)	July 29, 1959 Cape Elizabeth, Me. (43°28′N–70°12′W)	159	26
July 7, 1956 Boon Island, Me. (43°05′N–70°28′W)	July 21, 1960 Cape Elizabeth, Me. (43°27′N–70°12′W)	210	25
July 8, 1956 Cape Ann, Mass. (42°48′N–70°15′W)	Nov. 15, 1956 Cape Elizabeth, Me. (43°28′N–70°10′W)	18	40
July 8, 1956 Cape Ann, Mass. (42°48′N–70°15′W)	March 2, 1957 Cape Ann, Mass. (42°38′N–70°17′W)	34	10
July 8, 1956 Cape Ann, Mass. (42°48′N–70°15′W)	May 22, 1957 Chatham, Mass. (41°40′N–69°42′W)	48	73
July 8, 1956 Cape Ann, Mass. (42°48′N–70°15′W)	July 16, 1959 Cape Elizabeth, Me. (43°28′N–70°10′W)	157	40
Oct. 14, 1957 Browns Bank (42°36′N–65°46′W)	July 12, 1958 Chance Harbour, N.B. (44°55′N–66°21′W)	39	140

In July 1956, 155 specimens were tagged with Petersen discs attached with stainless steel pins through the snout. The fish were released in two locations in the Gulf of Maine; two miles south of Boon Island, Maine, and 18 miles northeast of Cape Ann, Massachusetts. In October 1957, 50 dogfish were similarly tagged and released on Browns Bank, 57 miles south of Cape Sable, Nova Scotia.

To date, eight tagged spiny dogfish (3.9 percent) have been recaptured; seven from the 1956 experiment and one from the 1957 experiment (Table 1). The length of time at liberty ranged from 18 to 210 weeks. Six fish were recaptured less than 50 miles from the tagging area while two were recaptured 73 miles and 140 miles away, respectively.

The tagged fish were recaptured relatively close to the areas in which they had been released. This is in contrast to previous tagging experiments with spiny dogfish off the coast of Newfoundland in which some of the fish were recaptured as far as 1300 miles from the point of release (Temple-

man, *op. cit.*; 1954, *J. Fish. Res. Bd. Canada 11(4): 351–4*, 1958, *Progr. Rep. Atl. Cst. Sta. (70):28–30.*).

The season of recapture is worthy of note in the cases of four fish recaptured at the same time of year, one to four years later. Similarly, four fish were caught in approximately the same location off Cape Elizabeth, Maine, over a span of four years, suggesting the possibility of the same fish schooling together for long periods of time.

It would be presumptuous to try to draw any conclusions about dogfish migrations based on the present limited marking program. However, the tag returns received so far warrant being placed on record for the benefit of biologists who may be interested in the life history of the spiny dogfish.

The recaptures indicate that spiny dogfish return to the same general area at about the same time of year, but as yet, the limited number of returns do not confirm either a north-south or inshore-offshore migration.

Additional tagging experiments, using a plastic spaghetti tag, have been carried out since the experiments reported here. Recaptures from the recent experiments will be reported on from time to time.—ALBERT C. JENSEN, *U. S. Department of the Interior, Fish and Wildlife Service, Bureau of Commercial Fisheries, Biological Laboratory, Woods Hole, Massachusetts.*

SIZE DISTRIBUTION BY DEPTH OF THE LONGFIN HAKE, *PHYCIS CHESTERI*.—The longfin hake, *Phycis chesteri* Goode and Bean, is one of the many species of hakes inhabiting the waters off the Atlantic coast of the Untied States. Because of its deep-water habits, very little is known about the biology and general habits of this species. Bigelow and Schroeder (1953, *U. S. Fish. Wildl. Serv. Fish. Bull. 53:232*) report it to be abundant on the slope of the continental slope of North America from the Laurentian Channel in Cabot Strait to abreast of Cape Lookout, North Carolina. Bigelow and Schroeder (1936, *Bull. U. S. Bur. Fish. 48(20):339*) and Schroeder (1955, *Deep Sea Res. 3(suppl.):358–72*) defined the depth distribution of the longfin hake in the Gulf of Maine as being from 70 to 140 fathoms and along the continental slope from 200 to 450 fathoms. W. C. Schroeder (personal communication) of the Woods Hole Oceanographic Institution caught *P. chesteri* as deep as 720 fathoms on an exploratory cruise in 1953. None of these reports includes length frequencies.

Recent cruises conducted by the Bureau of Commercial Fisheries in August and December 1959 and February 1960 have added information on the distribution of the longfin hake. In August 1959, we made otter trawl tows at each 100-fathom depth from 100 to 1000 fathoms along the continental slope off Block Island, Rhode Island (Lat. 40° 00′ N. – Long. 70° 59′ W. to Lat. 39° 46′ N. – Long. 71° 27′ W.). Due to the uneven bottom, it was not possible to tow exactly along a prescribed isobath. The gear was, therefore, towed in those areas where the range in depth over the distance of a tow did not exceed 100 fathoms. The data indicate that the longfin hake were distributed by size according to depth. The length frequency distribution of *P. chesteri* by depth is presented in Table 1.

It can be seen that, in August 1959, hake from 10 to 32 cm. in length (mean length 18.5 cm.) were found at the 100- to 200-fathom depth.

TABLE 1.—SIZE DISTRIBUTION BY DEPTH OF THE LONGFIN HAKE, *Phycis chesteri*.

Date	August 1959					Dec. 1959		Feb. 1960	
Depth (fathoms)	100–200	200–300	300–400	400–500	500–600	100–200	200–300	100–200	200–300
Fish length (cm.)									
9	—	—	—	—	—	—	—	—	—
10	2	*	—	—	—	—	—	—	2
11	4		—	—	—	—	—	—	—
12	2		—	—	—	—	—	—	—
13	1		—	—	—	—	—	—	—
14	1		—	—	—	—	—	—	—
15	9		—	—	—	—	—	—	—
16	23		—	—	—	—	—	—	3
17	29		—	—	—	—	—	—	4
18	45		—	—	—	1	1	—	19
19	42		—	—	—	—	1	—	14
20	32		—	—	—	—	2	—	15
21	14		—	—	—	—	3	—	34
22	2		—	—	—	—	—	—	40
23	1		—	—	—	—	1	—	37
24	1		—	2	—	—	—	—	19
25	1		—	—	—	—	—	—	11
26	3		—	1	—	1	—	—	15
27	1		1	6	—	1	—	—	10
28	3		—	1	—	—	—	—	14
29	—		2	2	—	1	3	—	16
30	2		3	3	—	1	—	—	22
31	1		2	2	—	—	1	—	18
32	1		2	6	—	—	1	—	18
33	—		1	12	—	—	1	—	8
34	—		4	18	—	—	—	—	10
35	—		5	23	—	—	—	—	4
36	—		—	22	1	—	—	—	6
37	—		—	14	—	—	—	—	3
38	—		2	12	—	—	—	—	—
39	—		—	10	1	—	—	—	—
40	—		—	2	—	—	—	1	—
41	—		—	1	—	—	—	—	—
42	—		—	1	—	—	—	—	—
No of fish	220		22	101	2	5	14	1	342
Mean length	18.5		32.7	34.3	37.5	26.0	24.7	—	25.1

*No sample.

Larger hake ranging from 27 to 38 cm. in length, with a mean length of 32.7 cm. were found in 300 to 400 fathoms. The range in length for the hake caught between 400 and 500 fathoms was from 24 to 42 cm. with a mean length of 34.8 cm. The catch for the depth between 500 and 600 fathoms contained only two fish which measured 36 and 39 cm. in length. No longfin hake were caught in depths greater than 600 fathoms.

In December 1959 and February 1960, we fished from 20 to 300 fathoms in the same general area. The gear on these cruises was not rigged to fish deeper than 300 fathoms so no direct comparisons are possible. The largest number (356) of hake were caught between 200 and 300 fathoms as compared with the tows made in the 100-fathom depth, where only six hake were caught. The length frequencies from these cruises are included in Table 1, to show the size distribution for the 200- to 300-fathom depth. The longfin hake taken on these cruises ranged from 16 to 37 cm. in length, with a mean length of 25.4 cm.

From these data, it can be seen that longfin hake tend to be distributed by size according to depth along the continental slope. The largest longfin hake measured 42 cm. and was taken between 400 and 500 fathoms.—RAYMOND L. FRITZ, *U. S. Department of the Interior, Fish and Wildlife Service, Bureau of Commercial Fisheries, Biological Laboratory, Woods Hole, Massachusetts.*

SPAWNING BEHAVIOR AND EGG RAFT MORPHOLOGY OF THE OCELLATED FRINGED FROGFISH, *ANTENNARIUS NUMMIFER* (CUVIER).—References to reproduction of the pediculate fishes by means of mucoid rafts are common in the literature. Especially well-known to scientists and seafarers is that of the goosefish, *Lophius americanus* Valenciennes, the huge raft of which may reach 1 or 2 feet in width, 40 feet in length, and 30 pounds in weight (Breder, 1948. *Field Book of Marine Fishes of the Atlantic Coast, G. P. Putnam's Sons, p. 301*). *Antennarius* rafts 3 feet in length and 5 to 6 inches in width have been observed in the Bahamas by Rasquin, (1958. *Bull. Amer. Mus. Nat. Hist. 114(4):327–72.*). Presumably the rafts of some large Pacific *Antennarius* are even longer than this.

Also well documented is the frequent raft production of the sargassumfish, *Histrio histrio* (Linnaeus), in captivity. Breder (1949. *Bull. Amer. Mus. Nat. Hist. 94(2):83–106*) observed nine spawnings in which the intervals between spawnings averaged 10.4 days (range 3 to 30 days). Mosher (1954. *Zoologica 39(12):141–52*) recorded nine spawnings of two individuals in which the intervals averaged 3.6 days (range 3 to 6 days). Rasquin (*op. cit.*), who has accumulated the most data on *Histrio*, recorded 164 spawnings of 12 individuals in which the intervals between spawnings averaged 5.7 days (range 1 to 39 days). She added extensive information on the production of the raft from a template of the lamellar and lining epithelia of the ovary, the shape of the raft being determined by the shape of the inner ovarian surface. After the raft is extruded, it fills with sea water along channels left by the structure of the lamellar epithelium. The raft of *Histrio* is scroll-shaped, 3 to 12 inches in length and 1 to 2 inches in width. The eggs within it are 0.65–0.70 mm. in diameter. It remains intact for three days until the time of hatching, when it disintegrates. Rasquin also reported that flat or scroll-shaped *Antennarius* rafts have been observed.

On September 4, 1957, the New York Aquarium received two yellow-brown specimens of *Antennarius*, each 4 inches long, from a local aquarium dealer whose source of supply was the Philippines. These were tentatively identified, while still living, as the ocellated fringed frogfish, *Antennarius nummifer* (Cuvier). These fish lived until the summer of 1958 and were inadvertently destroyed after their death. Confirmation of the identification was accomplished when the Aquarium received another specimen in 1960, undoubtedly of the same species and identified preserved by the use of Schultz (1957. *Proc. U. S. Nat. Mus. 107(3383):102–3*).

The fishes produced, always at night, except for the January 7 spawning, 13 egg rafts which were discovered floating in the tank on the mornings of the following days: 1957—September 9 and 30; October 2, 5, 14 and 21; December 16, 22, and 30; 1958—January 7 and 9, May 3, July 5.

No calculation of the average interval between these spawnings is made, since it is possible that some rafts were not recorded in the daily maintenance and cleaning of the tank, which was on public display. Nevertheless, it is apparent that this species, too, is highly prolific, sometimes producing rafts at three-day intervals. It is also possible that there are periods of high productivity, such as the one of September and October 1957 and that of December 1957 and January 1958, since the fish were in good condition during the intervening month of November but did not produce rafts.

The raft was not flat or scrolled as described for other pediculates, but took the form of a perforated balloon with a single entrance for water at its base. The ovary is thus presumed to be globular as well. Dimensions and morphology are given in Fig. 1, sketched on September 30 from the raft produced that day. The mass was very slightly positively buoyant and floated with the perforated base down. It was colorless, transparent

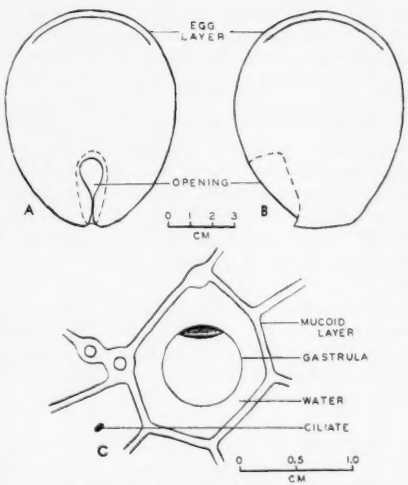


Fig. 1. Egg raft of the ocellated fringed frogfish, *Antennarius nummifer* (Cuvier): A. viewed from the front; B. viewed from the side, where the dotted lines represent folds that are inverted inward, forming the borders of the opening at the base of the raft; and C. a single mucoid egg chamber, in which note that when the raft filled with water after being extruded, a ciliate entered a chamber.

and fairly resilient and tough. The eggs were 0.7 mm. in diameter, and the raft was composed of three layers of eggs, each in a separate mucoid chamber 1.0–1.5 mm. in diameter. An approximate count of eggs in this mass was made by determining the number found in a cm.^{2} one-egg-layer thick (81), multiplying by the number of layers ($3 \times 81 = 243$) and again multiplying by the approximate surface area of the raft (201 cm.^{2} $\times$ 243). The total thus calculated is 48,800 eggs, and we may assume from this high figure that in nature mortality is exceedingly high. At the time this count was made, perhaps a half-day following spawning, the eggs had advanced to the gastrula stage, similar to Rasquin's stage 9 or 10 for *Histrio*. By October 2, three days following spawning, the raft had begun to break up. No young were seen.

At the time of the spawning on January 7, a *Histrio* three inches long was being kept with the two *Antennarius*. This spawning was observed by one of the tankmen, and he described an association between *Histrio* and *Antennarius* in which he suspected that the former "pushed the eggs out" of the latter by rubbing against her. The writer also observed repeated rubbing of the belly of the frogfish by the sargassumfish at non-spawning times. The sargassumfish approached the frogfish from slightly below and to the side, with fins widespread, and rubbed the belly of the frogfish with its side and belly. The motivation for interaction between these species could not be ascertained. It could be sexual or aggressive behavior.—CARLETON RAY, *New York Aquarium, New York Zoological Society, Brooklyn 24, New York.*

OCCURRENCE OF A NATURAL INTERGENERIC ETHEOSTOMATINE FISH HYBRID.—On October 10, 1960, we collected a hybrid darter from the San Marcos River at the original site of San Marcos, 3 miles east of the present city in Hays County, Texas. Mr. Richard Hewitt and Dr. and Mrs. H. G. Merriam assisted us in the field work. It was identified in the field as a hybrid between *Etheostoma spectabile* and *Hadropterus scierus*. Subsequent examination in the laboratory supports the field identification. The rather broad head, well developed color pattern without any differentiation of the gonad, absence of both the enlarged spinous belly scales and urogenital papilla are attributes found in hybrids between the primitive darters (*Hadropterus* and *Percina*) and the specialized species (*Etheostoma*). *Hadropterus scierus, H. shumardi,* and *P. caprodes* are the three primitive darters in the area. *Etheostoma spectabile, E. lepidum,* and *E. fonticola* are the three local specialized darters.

It is unlikely that *E. fonticola* is the specialized parent. The hybrid has a complete lateral line, 58 lateral line scales, and 12 dorsal spines. These are all attributes unlikely for any hybrid with *E. fonticola*. It is equally unlikely that *H. shumardi* is one of the parents. The hybrid has a dark base to the entire spinous dorsal, a faint subocular bar, and well developed lateral blotches. All of these are atypical of *H. shumardi* and both specialized darters. *Percina caprodes* can readily be eliminated. The lateral line scales are too few; the snout does not overhang; the lateral blotches are much too solid to be intermediate between *P. caprodes* and either remaining species of *Etheostoma*. This leaves *H. scierus* as the likely unspecialized parent and either *E. spectabile* or *E. lepidum* as the specialized one. The lateral line scale number is not quite high enough for hybrids between *H. scierus* and *E. lepidum*; however, its phylogenetic position and population frequency in the area are so similar to that of *E. speclabile* that the conclusions are valid if *E. lepidum* is the specialized parent. The meristic characters of the hybrid are almost midway between those of the suspected parental forms. The figures used for *H. scierus* are of specimens from San Marcos (C. Hubbs, 1954, *Am. Midland Nat. 52:211–20*) and those for *E. spectabile* are from C. Hubbs and Strawn (1957, *Evolution 11:1–10*). The average figures for *H. scierus* are listed first, followed by that of the hybrid in parenthesis, and at the end the averages for *E. spectabile* are given: lateral

line 69, (58) 50; spinous dorsal rays 12, (11) 10; soft dorsal rays 12, (13) 13; anal rays 10 or 11, (9) 9 and pectoral rays 12, (13) 14. Likewise the color pattern is intermediate. Although F_1 darter hybrids can be extremely variable (C. Hubbs and Strawn, 1957, *Evolution 11:1–10*), they are typically intermediate, and use of character indices is valid in determining parental forms (C. L. Hubbs, 1955, *Syst. Zool. 4:1–20*).

This hypothesis is supported by comparing the field hybrid with a variety of laboratory hybrids between known parents. The *H. scierus* × *E. spectabile* hybrids are the only ones that closely resemble the field hybrid. The meristic characteristics of the field hybrid are those typical for the known laboratory hybrids. The color patterns are similar, including: the extent and number of lateral blotches which are superimposed with speckles; the dark base of the spinous dorsal membranes; the faint suborbital bar; the six or seven dark dorsal saddles; and, the faint diffuse caudal speckling. The field hybrid has a distinct submarginal orange mark on the spinous dorsal, which was present on the laboratory hybrids before preservation. Likewise the colors of the laboratory hybrids are faint, due to their preservation for three to five years. Finally, the laboratory hybrids are deeper-bodied than the field hybrid, a phenomenon typical of fishes reared in this laboratory (for example see: Hubbs and Springer, 1957, *Texas J. Sci. 9:279–327*). The opercles of the *H. scierus* and the hybrid are heavily scaled, while *E. spectabile* seldom has these scales; however, laboratory hybrids have equally developed opercular scalation. The gonad has the appearance of a mass of adipose cells, which is typical of intergeneric darter hybrids.

C. L. Hubbs (1955, *Syst. Zool. 4:1–20*) showed that hybridization occurred between many fish species in nature. He reported that "among the thousands of specimens examined by me only two represent natural crosses between the more primitive and the more specialized genera." This individual constitutes the third known occurrence of this type of hybrid and the first which has been reported in more detail. The field hybrid is not unexpected as the cross can be easily made in the laboratory (C. Hubbs and Strawn, 1957, *J. Exper. Zool. 134:33–62*; C. Hubbs, 1959, *Texas J. Sci. 11:49–56*).

The occurrence of natural hybrids appears to be related to one or more phenomena, including: restricted and similar breeding sites; disturbance of the environment; and, scarcity of one parental species and abundance of the other (C. L. Hubbs, 1955, *Syst. Zool. 4:1–20*; In Press, Vertebrate Speciation, *The University of Texas Press*). Obviously gametic compatibility and other factors must also be favorable. The capture of this field hybrid is fortuitous in that the relative numbers of the parental species at the locality of capture is known for the preceding two years. This site has been used to obtain stocks of *H. scierus* for experiments; the egg complements of that species from San Marcos reported by C. Hubbs and Johnson (In Press, *Southwest. Nat.*) were primarily based on specimens from this locality. During the same time only three *E. spectabile* specimens were obtained. Therefore one of the rare *E. spectabile* may have entered a breeding unit of *H. scierus* because it could not find an appropriate mate. It has been suggested that the extensive collecting may constitute an environmental disturbance which would enhance hybrid formation.—CLARK HUBBS and CHARLES MICHAEL LARITZ, *Department of Zoology, The University of Texas, Austin.*

LIFE HISTORY NOTES ON THE ROUGHTAIL STINGRAY, *DASYATIS CENTROURA* (MITCHILL).—Recent fishery explorations by the U. S. Bureau of Commercial Fisheries M/V *Oregon* and the M/V *Silver Bay* have revealed some unknown aspects of the life history of the roughtail stingray, *Dasyatis centroura* (Mitchill). Previously, the most southerly record was a specimen taken in the vicinity of Cape Hatteras, North Carolina, by the M/V *Albatross* III (1953, Bigelow and Schroeder, *Fishes of the Western North Atlantic, I, part 2:359*) although Phillips (1956, *Copeia (4):249*) reported the species off Miami, Florida, from examination of a tail preserved by a local taxidermist.

During trawling operations by the *Silver Bay* in the littoral waters off the Atlantic coast of the southern United States, *D. centroura* was taken at 14 stations between Cape Hatteras and New Smyrna Beach, Florida (Table 1). It has also been taken at three stations in the northern Gulf of Mexico by the *Oregon* (1956, Springer and Bullis, *U. S. Fish and Wildl. Serv. Spec. Sci. Rept. Fish. No. 196:45*). In addition to these Gulf of Mexico records, one author (Bullis) has seen a number of specimens taken by shrimp trawlers in the vicinity of the Mississippi River Delta area, particularly on the eastern side, but the species is not so frequently encountered as is *Dasyatis americana* Hildebrand and Schroeder. Thus it appears that *D. centroura* has a range extending from Cape Cod, Massachusetts, to at least the Mississippi River Delta.

The maximum disc width recorded by Bigelow and Schroeder (*op. cit.* p. 357) for *D. centroura* was 60 inches. New records prove that this species reaches a considerably greater size. A specimen taken at *Oregon* station 2194 was photographed, but not measured. Determinations from the pho-

TABLE 1.—SUMMARY OF 20 SPECIMENS OF THE STINGRAY, *Dasyatis centroura*, TAKEN BY THE M/V *Silver Bay* OFF THE ATLANTIC COAST OF SOUTHERN UNITED STATES

Station Number	Location of Capture			Depth (fathoms)	Sex	Disc Width (inches)	Weight (pounds)	Total Length (inches)	Water Temperatures °F.	
	(N. Latitude)	(W. Longitude)	Date						(Surface)	(Bottom)
1634	35°02′	75°26′	2/23/60	31	F	20	—	—	65	—
1634	35°02′	75°26′	2/23/60	31	F	18	—	—	65	—
1634	35°02′	75°26′	2/23/60	31	M	17	—	—	65	—
1502	34°00′	76°34′	12/8/59	22	M	—	—	—	64	69.4
1326	33°53′	78°18′	10/16/59	5	F	70(est.)	300(est.)	—	77	75
1328	33°46′	78°40′	10/16/59	5	—	—	—	—	75	75
1738	33°04′	77°59′	3/7/60	20	F	—	—	—	65	—
1733	33°00′	78°26′	3/7/60	17	M	—	—	—	60	58.6
1733	33°00′	78°26′	3/7/60	17	M	—	—	—	60	58.6
1360	32°51′	78°32′	10/20/60	20	—	—	—	—	78	—
1744	32°43′	78°59′	3/8/60	14	M	14	—	—	50	—
1743	32°37′	78°49′	3/8/60	19	F	—	—	—	59	—
1547	31°08′	80°22′	1/17/60	17	M	55	205	123	65	—
1547	31°08′	80°22′	1/17/60	17	M	51½	160	—	65	—
1539	30°39′	80°49′	1/16/60	14	F	55	175	118	60	—
1539	30°39′	80°49′	1/16/60	14	M	59½	205	126½	60	—
2133	30°22′	80°32′	6/12/60	20	M	61½	245	—	73	—
2133	30°22′	80°32′	6/12/60	20	F	62	285	—	73	—
2135	30°10′	80°33′	6/12/60	20	M	62½	315	—	78	—
1562	29°01′	80°42′	1/21/60	9	F	49	135	—	60	—

tograph, by comparison with known measurements, indicate that the disc of this specimen was approximately 82 inches wide and 77 inches in length. Weight was estimated at 700–800 pounds.

More reliable measurements were obtained from a female caught by a shrimp trawler off Mobile Bay in 13 fathoms and landed in Pascagoula, Mississippi, on March 21, 1960. It measured 76 inches across the disc and 71 inches from tip of snout to posterior edge of vent. The tail was missing. Bullis estimated the weight to be 500–600 pounds. There were no young in this specimen and the ovary was small and undeveloped.

Several specimens taken along the Atlantic coast south of Cape Hatteras by the *Silver Bay* were measured and weighed aboard the vessel. The heaviest was a 315 pound male from station 2135 that measured 62½ inches across the disc.

A most unusual capture was made at *Silver Bay* station 1326 of a 70-inch wide female, which gave birth to four young on the deck of the vessel. The young had estimated disc widths of 16–18 inches. The absence of yolk sacs indicated they were apparently near full term. Unfortunately, they were not preserved, but represent one of the few records of a gravid *D. centroura* or its brood size. Mansueti (1960, *Chesapeake Sci. 1(1):76*) found a female 35¼ inches broad with three heavily yolked eggs in the left ovary, from the Maryland part of Chesapeake Bay in September, 1959.

Previously, the smallest known *D. centroura* was a 15.7-inch-wide specimen from Woods Hole, Massachusetts, (Bigelow and Schroeder, *Op. cit. p. 357*). A 14-inch-wide male was caught at *Silver Bay* station 1744 off Charleston, South Carolina. This specimen showed no thorn or tubercle development. On the three specimens from station 1634 (see Table 1) thorn development is well advanced in the tail region posterior to the origin of the caudal spine. On the 20-inch specimen a single large tubercle had formed at the base of the caudal spine.

D. centroura has been tentatively considered a member of the warm season fauna of coastal waters from Cape Cod and Georges Bank to Chesapeake Bay (Bigelow and Schroeder, *Op. cit. p. 359*). It has been suggested that this species simply withdraws to deeper waters during the winter months. In the light of these new findings, the possibility of a southerly migration better explains the winter absence of *D. centroura* from the northern extent of its range.

Although *D. centroura* has been abundantly represented in the northern waters for many years, nothing was known about the breeding habits or the young. This could be explained by the hypothesis that the breeding population lies farther to the south, and that all specimens previously examined were merely seasonal migrants to the northern limits of the range. This is supported by the paucity of sexually mature individuals in the north, the aforementioned gravid

female from the vicinity of Cape Fear, North Carolina, and the four small, evidently recently born, specimens off Charleston and Cape Hatteras.

A large female *D. centroura* was caught in a trawl off the western edge of Great Bahama Bank on November 5, 1960, at *Silver Bay* station 2456 (23°39′ North lat., 79°06′ West long.) in a depth of 150 fathoms. This appears to be a maximum depth record for dasyatids. The disc width of the specimen was 70.4 inches, total length 131.5 inches, and it weighed 409 pounds. Gross examination revealed 10 eggs in the left ovary, ranging from 4 to 15 mm. in diameter. The stomach contained the remains of approximately 50 small eels.

The relationship of *D. centroura* to an extralimital species, *Dasyatis aspera* (Cuvier) is complicated by this new knowledge. Bigelow and Schroeder (p. 357) stated that some students have considered *D. aspera* of the Mediterranean and tropical West Africa to be identical to *D. centroura*. However, they considered them as separate species since they apparently inhabited two different thermal zones—*D. centroura* the temperate zone and *D. aspera* the tropical-subtropical zones. The new tropical-subtropical locations for *D. centroura* in the Gulf of Mexico and Bahamas tend to increase the doubt of dual specificity.

The records cited, which extend the recorded range of the roughtail stingray to our South Atlantic and Gulf coasts and the Bahamas lend credence to the identification of a stingray tentatively accepted as *D. centroura* from off Los Pocitos Beach, Uruguay (Bigelow and Schroeder, *Op. cit.* p. 360). This record indicates that *D. centroura* may have a range extending along the entire Western Atlantic coast, from Cape Cod to southern South America. Lack of records from the intermediate portion of this area might be attributed to limited investigational work as well as to confusion with *D. americana*.—Harvey R. Bullis, Jr. and Paul Struhsaker, *U. S. Fish and Wildlife Service, Bureau of Commercial Fisheries, Pascagoula, Mississippi and Brunswick, Georgia.*

SALINITY AND SIZE IN MARINE FISHES.—Many motile organisms along sea coasts with estuarine areas have a similar life history. Spawning takes place in high salinity water, but the young grow up in low salinity water and return to the sea to spawn. The seaward movement of the young into waters of high salinity, as they grow larger, leads to a direct correlation between salinity and size. Weymouth, Lindner and Anderson (1933, *Bull. U. S. Bur. Fish 48:1–25*) first specifically mentioned the principle, as applied to one species of shrimp and I (Gunter, 1945, *Publ. Inst. Mar. Sci. Univ. Texas 1:1–190*, and 1950, *Ibid. 2:7–51*) enunciated it as a general principle applying to both invertebrates and fishes. The question of whether or not the correlation is a true one, dependent upon salinity itself or upon other factors, remains to be answered.

Some workers in marine biology are impressed with the importance of the salinity factor, but others believe, apparently, that it is a subsidiary matter. Segerstrale (1953, *Soc. Scient. Fenn. Comment. Biol. 13(15):1–7*) has shown that extensive faunistic changes took place in Baltic waters with increases in salinity amounting to only 0.6 parts per thousand over a four year period, and he concluded that the change was related to the salinity change. On the other hand, Reid (1956, *Southwest. Nat. 1(4):157–65*) said, in speaking of ichthyofaunal differences between a bay area and the Gulf beach, "In view of the relatively similar salinities of the upper part of East Bay and the Gulf (average difference about nine parts per thousand) . . . , we prefer to relate the association to habitat with all its inherent characteristics."

It behooves field workers and ecologists to present correct principles to the physiologists, who will ultimately give the answer to many basic questions concerning organic distributions in the sea. For that reason I feel that it is necessary to examine critically the paper of Reid and Hoese (*Copeia* 1958 *(3):225–31*), who conclude, "In summary, our studies in East Bay strongly indicate that salinity, *per se*, is not the cause of the size distribution cline of the two species studied." Their data concern two species of croakers, Family Sciaenidae, collected during the summer in three successive years in East Galveston Bay.

It should be noted in passing that Springer and Woodburn (1960, *Prof. Paps. No. 1, Florida State Board Conserv. Marine Lab. 104 p.*) have echoed the conclusions of Reid and Hoese without presenting data relating to the questions.

Several criteria should be used in definitive studies of salinity and size relations of marine animals.

1. Sampling should follow at least one annual cycle so as to cover the full size range of the species, and adequate samples of all sizes should be collected.

2. The full salinity range over which the species lives should be sampled.

3. Each specimen should be related specifically to the salinity at which it was caught. All data collected must be used and selection prejudices the case.

No study presented so far has satisfied all of these requirements, but Reid and Hoese (*op. cit.*) satisfied none of them.

The very smallest croakers were not available during the two summer months in which the authors worked over the three year period, and

some of the larger croakers taken were excluded from the data. A footnote, p. 227, states that only individuals in their first year were used and that "Insufficient numbers of older examples were taken to be of value."

Two criticisms of the procedure may be raised. Pearson (1929, *Bull. U. S. Bur. Fish. 44:129–214*) and Gunter (*1945, op. cit.*) both observed small croakers coming in the bays from the period of October through March, and Gunter found them entering in April. The croaker has a long spawning season and it is difficult to determine, through size alone, whether certain individuals taken in the summer were spawned in October and were 9 months old or were spawned the previous March and were 1 year and 3 months old. In fact the largest croaker included by Reid and Hoese, 95 mm. in standard length, falls rather close to the modal figure for the 0-year class in July (cf. Gunter, *1945, op cit. fig. 9*). There seems to be no doubt that the data applied only to fish in the first year, and possibly not to the whole size range of that class. Therefore, the authors would have done better to say that sizes above a certain arbitrary limit were excluded.

The second criticism is that there is no intrinsic reason why fish of only a single year class should be included in a discussion of salinity and size data. Were larger, older fish taken at lower salinities, which would have bolstered the author's ideas, excluded; or were larger fish taken at higher salinities, which would be contrary to the author's ideas, excluded? Such questions naturally arise when all data are not used. To say the least, all of the data were not presented, admittedly, and that procedure is highly questionable.

With regard to the second criterion listed above, it should be noted that both species of croakers listed are euryhaline (cf. Gunter, 1942, *Am. Midland. Nat. 28:305–26.*). A comparison of Figures 1 and 4 of Reid and Hoese show that the fish taken for the three different years were in waters ranging in salinity from 9–19, 16–28 and 15–21 *per mille*, respectively. These salinities cover a range of 16.7 to 33.3 per cent of the whole salinity range over which these fishes are known to live. The data do not include the lower and higher parts of the salinity range where the relations between salinity and size are most pronounced.

As a last criticism, it should be pointed out that Reid and Hoese did not really present their data. The size ranges of the fishes could have been related easily to the specific salinities at which they were caught or to specific salinity ranges. Instead the authors presented three figures of isohaline lines, which purport to represent the average salinity picture of East Galveston Bay for the summers of 1954, 1955 and 1956. These are stated to be based on the salinity means of the stations occupied, but the number of stations, their locale, and ranges of salinity over these stations are not shown. Hydrographers know that isohaline lines are not stable, especially in Texas bays, and in fact the average isohaline pictures presented probably do not represent any single time at which the fishes were caught. Collier and Hedgpeth (1950, *Pub. Inst. Mar. Sci. Univ. Texas 1(2):121–94*) said concerning the Texas meteorological regime, p. 138 "Anything can happen and often does..." I have not examined the Texas climatological data for storms and rains which have moved these isohaline lines about, for the evidence would be redundant.

The matter of the ranges which the mean isohaline lines represent are particularly important, when the data are examined in detail. Figure 2 shows no differences in the sizes of *Micropogon undulatus* at salinities ranging from about 20–24 to 17–18. From the latter salinities to the next stage there seemed to be a slight increase in size, which is taken as an increase in size with lowering salinity. But the areas, C and E, had salinity ranges of 17–18 and 16; the lowering salinity is not much and the fish measured numbered only 40 and 57, respectively. During the year 1956 there was a decrease in the size of croakers from Areas A to B and an increase from B to C to D. The salinity ranges at these four stations, as well as they can be determined by comparing the isohaline lines, figures 1 and 4, were: 15–16, 16–18, 14–16 and 17–18. The ranges are relatively small and at any one of the four stations the upper or lower salinity could have prevailed for a time with a movement in the isohaline line.

The data of Reid and Hoese only show what several other authors have shown, namely that mixed sizes of a species are commonly found at intermediate salinities. Their study was not properly designed to answer the questions posed, because of the small salinity ranges involved and other inadequacies pointed out above, and their sweeping conclusions are not supported by their data.

The relationship of salinity and size is an important aspect of estuarine biology and it deserves rigid and careful consideration.—G. GUNTER, *Field Laboratory, Texas Game and Fish Commission, Seabrook, Texas.*

GRASS PICKEREL, *ESOX AMERICANUS VERMICULATUS*, WITH SUPERNUMARY FINS.—Aberrant individuals, like those seen in hatcheries, are found in nature only when large series of specimens of a species are examined. In a study collection of the grass pickerel, *Esox*

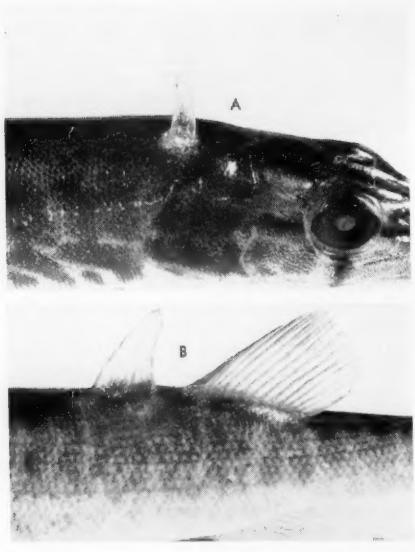


Fig. 1. Supernumerary fins in the grass pickerel, *Esox americanus vermiculatus*; A, specimen 75 mm. T. L. witn a small rayed fin behind the head; and B. specimen 190 mm. T. L. with a rayed fin anterior to the normal dorsal fin.

americanus vermiculatus LeSueur, two individuals (in 500) were discovered which had supernumerary fins on the dorsal surface.

The first (Fig. 1A), 75 mm T.L., had a small, rayed fin on the dorsal surface just behind the head and directly above the origin of the pectoral fin. This fin lay at an angle of about 45° left of the vertical. In structure, outline, ray characteristics and number (8) it corresponded with the normal pelvic fins of the individual. It had a fleshy base, rectangular shape, rounded tip and in no way resembled the true and normal dorsal fin. An X ray photo showed that this fin lacked bony support of any kind and bore no apparent association to the rest of the skeleton.

The other individual (Fig. 1B), 190 mm T.L., had a rayed fin 3.5 mm. in front of the normal dorsal fin. It was in the mid line, rectangular, somewhat pinched and curled toward the top as to appear pointed and lay at an angle of approximately 30° right of vertical. In general characteristics and size this fin resembled the dorsal fin. It was only slightly shorter in height than the true dorsal but had only one-third to one-half as long a base. This fin had 11 rays contrasting with 19 in the normal dorsal and only one anterior rudiment as opposed to four. Basal supportive structures were present but for only seven, the middle four rays lacking them. Even where basals were present they were short, curled, and lacked the proper association with the neural processes of the vertebrae.—E. J. CROSSMAN, *Department of Fishes, Royal Ontario Museum, Toronto 5, Ontario.*

WINTER ABUNDANCE OF *ARCTOGADUS GLACIALIS* IN THE POLAR BASIN.—Little is known of the winter distribution of fishes in the Polar Basin, and whatever fragments of information become available should be placed on record. A small collection of fishes recently made from a floating ice station by personnel of the Lamont Geological Observatory (Columbia University) throws some light on the biology of the little-known gadid genus *Arctogadus*. Under Contract AF 19 (604)-2030 from Air Force Cambridge Research Center, floating ice STATION CHARLIE was manned during 1959–60. The station drifted across the Chukchi Rise, located in the Eastern Basin of the Arctic Ocean northwest of Point Barrow, Alaska, during the summer and again during the winter. Bottom samples were dredged periodically and at regular intervals explosive charges were lowered through a "Shot-hole" in the ice and seismic blasts were set off 50 feet beneath the surface. Samples and readings were taken at a "Hydro-hole" about 50 feet away. Mr. Charles T. M. Chance forwarded three species of fish and some notes obtained from STATION CHARLIE.

Arctogadus glacialis (Peters). Four specimens, 148 to 238 mm. in standard length, taken from "Hydro-hole" after a seismic blast on December 11 at 76°51′ N. lat., 171°01′ W. long., depth 2220 meters. Thirty-one specimens, 121 mm. to 210 mm. in standard length, taken from "Hydro-hole" after a seismic blast on December 21 at 77°12′ N. lat., 168°12′ W. long., depth 540 meters.

The tips of the pelvic fins, though broken in some, reached to the anus or further back in 16 individuals; these appear to be males. The pectoral fins reach to the vertical of the anus or further back in all specimens. The barbel is microscopic in 34 fish; in one it is macroscopic but less than the diameter of the pupil of the eye. The long pelvic fins, long pectoral fins and small barbel indicate the specimens cannot be *A. borisovi Drjagin* (cf. Svetovidov, 1948, *Fauna SSSR Ryby 9(4):206–7*; Andriashev, 1954, *Ryby severnykh morey SSSR 188–90*). In *A. pearyi* (Nichols and Maxwell) the barbel is either obsolete or it exceeds the pupil and there are 32–34 gillrakers (6 specimens; Walters, 1955, *Bull. Am. Mus. Nat. Hist. 106(5):303*), whereas in *A. glacialis* (Peters) the barbel is obsolete or rudimentary and there are 27–32 gillrakers (count on 7 specimens; Andriashev, 1957, *Zool. Zhurn. 36(2):1747–*

9). The fishes from STATION CHARLIE have 27–34 gillrakers in 34 specimens, with a mean of 30.0; only 6 fish or 17.6 percent of the sample have 32–34 gillrakers. On the basis of barbel size and number of gillrakers, the STATION CHARLIE fishes are identified as *A. glacialis*.

According to Mr. Chance the first cod was obtained on November 23, when the position of the station was 77°51′ N. lat., 172°36′ W. long., depth 2226 meters. The fish became increasingly abundant in the "Hydro-hole" on the days following. On December 21, 51 were taken from the "Hydro-hole" of which the 31 listed above were saved. Between December 21 and January 3 the "Hydro-hole" yielded 50 to 70 individuals daily. On January 3 more than 500 by actual count were removed from the "Hydro-hole" and an almost equal number were cleaned out of the "Shot-hole". The position of STATION CHARLIE on January 3 was 77°11′ N. lat., 167°43′ W. long., depth 530 meters. The station was abandoned shortly thereafter.

Since cod were obtained only in winter and only when STATION CHARLIE was in the neighborhood of the Chukchi Rise it is plain the fish were not following the ice in its drifting movements but rather the drifting ice passed over the aggregations of fish. None were obtained in the vicinity of the Chukchi Rise during the preceding summer. Yet according to Mr. Chance dredge hauls yielded gadid otoliths in greatest numbers in the vicinity of the Chukchi Rise. In the *A. glacialis* I examined, no females have ripe ovaries while all specimens have stomachs full of small crustaceans and there are large fat deposits in their body cavities. For economy of hypothesis it is assumed that no other species of cod were obtained by STATION CHARLIE during the interval November 23 to January 3. These bits of evidence indicate that schools of *Arctogadus glacialis* regularly undertake a midwinter feeding migration across the shallow waters of the Chukchi Rise. The schools may migrate in a general southwesterly direction since Andriashev's (1957, *ibid.*) sample of 11 fish had been taken from a floating ice station on February 24 at 75°34′ N. lat., 174°16′ E. long.

Lycodes frigidus Collett. One immature individual, 146 mm. in standard length, was dredged up on November 30 at 77°37.7′ N. lat., 172°43′ W. long., depth 2215 meters. This appears to be the first record of the species from the Eastern Basin though it is widely distributed in the Central Arctic Basin and ranges southward into the North Atlantic, always at great depths.

Careproctus reinhardti Kröyer. One young individual, 57 mm. in standard length, is tentatively assigned to this species. It was collected by dredging on July 25 at 77°45.5′ N. lat., 163° 48.6′ W. long., depth 260 meters. If the identification is correct, this represents a first record for the Eastern Basin.—Vladimir Walters, *Lamont Geological Observatory, (Columbia University), Palisades, New York, Contribution No. 493.*

OBSERVATIONS ON THE SPAWNING OF SURGEONFISHES (ACANTHURIDAE) IN THE SOCIETY ISLANDS.—Few observations have been made on the actual spawning of marine fishes, and nothing has been found in the literature concerning the reproduction of surgeonfishes. The author was fortunate to observe the spawning of two acanthurids in the Society Islands, *Ctenochaetus striatus* (Quoy and Gaimard) and *Zebrasoma scopas* (Cuvier). A detailed account of the spawning of a third surgeonfish, *Acanthurus triostegus* (Linnaeus), in the Tuamotu Archipelago appears in a large paper dealing with the biology of this species (Randall, in press, *Pacific Science*).

Ctenochaetus striatus is the most common acanthurid and perhaps the most abundant reef fish of moderate size (it attains about 200 mm. standard length) in the Society Islands. It appears uniform dark brown underwater; however, if seen at close range, blue longitudinal lines may be visible on the body and small orange spots on the head. The spawning of this species was observed in Tahiti on February 17, 1957, in Ava Iti Pass, a passage about 50 feet deep through the barrier reef. The first indication of spawning was an unusual concentration of this fish on the northwest side of the pass at about 5 p.m. No further notice was taken until about an hour later when a striking color change of the fish became apparent which the author had not seen previously. Instead of appearing uniform dark brown, the fish were pale tan except for about the outer 6 mm. of the median fins, the mouth, and mid-dorsal part of the head and nape which were abruptly black (the mid-ventral region of the head was not seen; possibly a black band was present there too). The fish were aggregated linearly along the reef edge at a depth of about 8 to 25 feet. None was seen to swim to the bottom to feed. Nearly all in the group in the deeper levels exhibited the color change, but most of the fish near the surface were entirely dark. Possibly this difference was associated with the proximity of the observer at or near the surface, for the pale, dark-margined fish altered within a few seconds to dark brown when approached. They appeared to be just as wary of a swimmer at this time as during non-spawning periods. The fish were more active than usual and milled constantly. Actual spawning took place when about

three to five fish swam very rapidly upward about four to five feet above the main school and almost as rapidly down again. The fish remained remarkably close together during the ascent. There was no pause at the upper terminus of the vertical movement; the fish turned abruptly and dispersed as they returned to the school. A small cloud of white, presumably milt, could be seen at the peak of the movement. All of the fish in the small spawning groups seemed to be in the pale, dark-edged color phase. It was impossible to ascertain how many times individual fish participated in the spawning act, for this never took place closer than 15 feet, and in the failing light (darkness ensued at 7 p.m.) the individuals which had just spawned were soon lost in the main school. A female which was speared was distended with transparent eggs less than 1 mm in diameter which were readily released by applying slight pressure to the abdomen. No interference from other species of fishes was observed.

On May 8, 1957, at about 5 to 6 p.m., in the lagoon of Raiatea near the pass off Uturoa, the dark brown *Zebrasoma scopas* was observed to spawn. As with *C. striatus*, a milling aggregation first attracted attention. Several small schools were noted at depths of 10 to 20 feet over coral heads at the edge of the deep part of the lagoon next to the barrier reef. Fish were seen chasing one another, and none was feeding. No color change was apparent. The same sudden upward swimming of small groups of fish, followed by downward movement and dispersal occurred; however the spawning groups usually consisted of eight to 10 fish and their movements were less rapid and not as consistently vertical (*i.e.* more often diagonally upward) as those of *C. striatus*. Five specimens of *Z. scopas* were speared at this time; all were running ripe males or females.

The three different acanthurids which were observed spawning had all chosen localities where a strong current set to the open sea.

Also common to all three was the time of day at which spawning took place, dusk. Prior to any of these observations of spawning acanthurids, considerable effort was expended to observe the reproduction of *Acanthurus triostegus* in Hawaii during hours of bright sunlight, but without success. The data from counting the numbers of ripe females in samples of adequate size throughout the period of a month in the spawning season (December to July) indicate that about 90 percent of the spawning of *triostegus* occurs from 12 days before to two days after full moon. It was then thought that spawning might take place at night when the moon was shining. Repeated night diving with an underwater light failed to reveal any reproductive activity. After chancing upon spawning fish in the Tuamotus at dusk, it was realized that no concerted attempt had been made to watch these fish in Hawaii at this time of day. Spawning late in the day is probably characteristic of *A. triostegus* and perhaps of all acanthurids. At Cat Cay in the Bahamas in early May, 1958, a large group of blue tang, *Acanthurus coeruleus* (Bloch and Schneider), was seen actively milling about very late in the day in the same manner as the acanthurids previously discussed, and it is believed that this represented pre-spawning behavior. It was necessary to leave the area while some daylight prevailed, and no actual spawning was observed.

The preponderance of spawning near the time of full moon by *A. triostegus* may apply to other acanthurids. These fortuitous observations of the spawning of surgeonfishes were all made within five days of full moon.

The most striking feature of the spawning of these fishes is the sudden upward rush, release of sperm and eggs at the acme of this movement, followed by downward swimming to rejoin the main group of fish. This same pattern has been noted for five West Indian parrotfishes (Scaridae) and one wrasse, *Thalassoma bifasciatum* (Bloch) (Randall, ms), all of which lay pelagic eggs. At first it was thought that the rapid upward movement served the purpose of confusing possible predators. It is now believed that the primary function of this movement is to facilitate the release of eggs and sperm by the expansion of the airbladder within the body cavity due to the lowering of pressure by swift upward swimming. The flexure of the bodies of the fishes at the peak of their movement as they turn sharply to head downward probably also helps release gonadal products. The abrupt change in direction following the fleet upward dash at the moment eggs and sperm are extruded may assist in their mixture and dispersal.—JOHN E. RANDALL, *The Marine Laboratory, University of Miami.* Contribution No. 312.

THE NOMENCLATURE OF *XYRICHTYS* CUVIER, 1815.—The worldwide razorfish genus *Xyrichtys* is most commonly spelled *Xyrichthys* presumably because it appeared in this latter form in the well known work by Quoy and Gaimard (1824, *Voyage Autour du Monde.... L'Uranie et La Physicienne, Zoologie p. 284*). However, as both Neave (1940, *Nomenclator Zoologicus 4:683*) and Sherborn (1932, *Index Animalium, Sect. 2, pt. 28, p. 7029*) have indicated, the genus was originally described by Cuvier (1815, *Mémoires du Museum d'Histoire Naturelle, 1:329*) some nine years earlier. Dr. Giles W. Mead has kindly examined a copy of Cuvier's

paper in the library of the Museum of Comparative Zoology at Cambridge and reports that *Xyrichtys* is indeed the original spelling.—JOHN C. BRIGGS, *Institute of Fisheries, University of British Columbia, Vancouver 8, Canada.*

FOOD HABITS OF TWO DASYATID RAYS IN DELAWARE BAY.—During the summer of 1958 studies were made on the biology of several species of clasmobranchs as they occur in Delaware Bay. Among those observed were two of the dasyatid rays, *Dasyatis sayi* and *Dasyatis centroura*. Included in the studies were the food and feeding habits of these animals. Bigelow and Schroeder (1953, *Mem. Sears Found. Mar. Res. 1(2):358, 384–5*) state that both *D. sayi* and *D. centroura* are not especially active feeders and spend most of their time buried in the sand and mud flats. The stomachs of *D. centroura* examined near Woods Hole, Massachusetts, contained a large number of crabs (*Cancer*), clams (*Mya*), and large gastropods (*Polinices*), as well as squid (*Loligo*), annelid worms and a few fish fragments. These same authors (*op. cit.*) describe *D. sayi* as feeding chiefly upon annelid worms, small bivalves, and in lesser amounts upon gastropods, amphipods, shrimps, crabs and fish. Gudger (1912, *Proc. Biol. Soc. Wash. 25:141–56*) reported the food of *D. sayi*, taken off Beaufort, North Carolina, to consist entirely of two species of annelid worms. Mansueti (1960, *Chesapeake Sci. 1(1):76–7*) reported the occurrence of fragments of the spot, *Leiostomus xanthurus*, and the menhaden, *Brevoortia tyrannus*, in the stomachs of *D. centroura* taken in the Chesapeake Bay. These may have come from bait used by fishermen.

Digestive tracts were removed and inspected for food items in 37 specimens of *D. sayi* and 54 specimens of *D. centroura* taken from Delaware Bay. The undigested items were removed from the tracts by flushing with water and drained for identification, weighing, and counting. Since both rays feed upon species also included in the food of the skates, *Raja eglanteria* and *Raja erinacea*, the average wet weights for food species as determined by Fitz (1956, *An Introduction to the Biology of* RAJA EGLANTERIA *and* RAJA ERINACEA *as they occur in Delaware Bay. Master's Thesis, Univ. of Del. 93 p.*) were used. Five methods were employed to analyze the stomach contents: (a) by numerical abundance, recording the actual numbers of the food items found in the stomachs, (b) by frequency of occurrence, indicating the number of times the different food items were found in the rays, (c) by an index of abundance, calculated by multiplying the percent by number for each food species by the percent of occurrence, (d) by the average number per stomach, determined by dividing the numbers of each species found by the number of stomachs examined, and (e) by the average wet weight per ray stomach. The grand average wet weight per stomach was established by multiplying the average wet weight for those sizes of each food species found in the stomachs by its numbers and adding.

The food analyses (Fig. 1 and Table 1) give qualitative and quantitative information on the diets of *D. sayi* and *D. centroura* found in Delaware Bay. A total of 14 food species were identified in the digestive tracts of both rays; five crustaceans, three molluscs, three annelids, and three teleosts. The percent of occurrence of these items in the rays examined are shown in Fig. 1. Table 1 indicates the relative importance of the various food species to the two rays.

The food habits of *D. sayi* and *D. centroura* found in Delaware Bay do not correspond strictly to those found by other investigators. Clams and gastropods play a very minor role while the crustacea (*Crago*) were of prime importance both in occurrence and numbers ingested.

Immediately apparent is the fact that both *D. sayi* and *D. centroura* ingest virtually the same food items, both in percent of occurrence and average number per stomach. The most consistently occurring items in both rays were *Crago septemspinosus*, 79 percent in *D. sayi* and 83 percent in *D. centroura*, and *Glycera dibranchiata*. In many cases *Crago* was the only food ingested. The average total wet weight of food

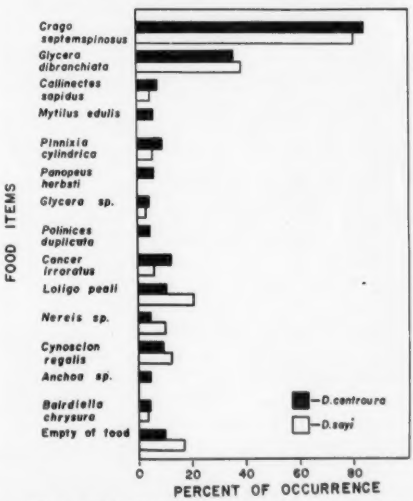


Fig. 1. Food items found in the stomachs of 37 specimens of *Dasyatis sayi* and 54 specimens of *D. centroura* from Delaware Bay during the summer of 1958.

TABLE 1.—FOOD ANALYSES FOR *Dasyatis centroura* AND *Dasyatis sayi* FROM DELAWARE BAY

Dasyatis centroura

Food species	No. of Food Items Counted		Percent of Occurrence	Index	Aver. No. Per Stomach	Aver. Wet Wgt. in Gms. of Food Species	Aver. Total Wet Wgt. in Gms. of Food Per Stomach
	Total	%					
Crago septemspinosus	1782	76.6	83	6355	117.77	0.12	14.13
Glycera dibranchiata	475	20.4	36	735	13.61	1.82	24.77
Callinectes sapidus	9	0.4	6	2	0.04	5.70	0.23
Mytilus edulis	7	0.3	4	1	0.02	2.00	0.04
Pinnixia cylindrica	7	0.3	7	2	0.04	4.20	0.17
Panopeus herbsti	5	0.2	4	1	0.02	3.20	0.06
Glycera sp.	6	0.3	3	1	0.01	1.82	0.02
Polinices duplicata	5	0.2	3	1	0.01	4.20	0.04
Cancer irroratus	11	0.5	9	4	0.08	5.20	0.42
Loligo peali	5	0.2	8	2	0.03	58.60	1.76
Nereis sp.	3	0.1	3	1	0.01	1.50	0.02
Cynoscion regalis	6	0.3	6	1	0.02	12.90	0.26
Anchoa sp.	3	0.1	3	1	0.01	10.60	0.11
Bairdiella chrysura	3	0.1	3	1	0.01	12.90	0.13
Total	2327				131.68		42.16

Dasyatis sayi

Crago septemspinosus	1484	88.6	79	6999	190.43	0.12	22.85
Glycera dibranchiata	133	7.9	39	311	8.75	1.82	15.93
Callinectes sapidus	7	0.4	2	1	0.02	5.70	0.11
Pinnixia cylindrica	9	0.5	3	2	0.04	4.20	0.17
Glycera sp.	2	0.1	2	1	0.01	1.80	0.02
Cancer irroratus	8	0.5	3	1	0.04	5.20	0.21
Loligo peali	9	0.5	12	6	0.17	58.60	9.96
Nereis sp.	7	0.4	7	3	0.08	1.50	0.12
Cynoscion regalis	14	0.8	11	9	0.24	12.90	3.10
Bairdiella chrysura	2	0.1	2	1	0.01	12.90	0.13
Total	1675				199.79		52.60

D. Centroura stomachs—with food—49, empty—5.
D. sayi stomachs—with food—30, empty—7.

species, however, de-emphasizes the importance of *C. septemspinosus* and emphasizes *G. dibranchiata* for *D. centroura*.

The index of relative abundance places a more correct evaluation on those items consistently eaten and again emphasizes the importance of *C. septemspinosus* and *G. dibranchiata* to both animals. By the same token the other food species are probably shown in a more true value.

The kinds of food items recorded in Fig. 1 and Table 1 suggest that these two species of rays taken from Delaware Bay feed not only on bottom forms, but frequently off the bottom on free-swimming organisms. On two separate commercial otter-trawl trips the net was rigged for fishing slightly off the bottom for weakfish. On both occasions a number of *D. sayi* and *D. centroura* were captured and contained a high percentage of weakfish remains.

It is further suggested that the rays feed upon the most abundant food item available in their environment. The percent of occurrence of obligate bottom forms compared to the incidence of non-obligate forms in stomach contents implies that the rays frequenting Delaware Bay have wide enough feeding habits to take advantage of the food species available. This is in contrast to the more obligate food items recorded by other workers (*Bigelow and Schroeder, op. cit.*).

Food and feeding habits have been used as a means to ascertain possible competition between organisms. Elton (1946, *J. Anim. Ecol. 15:54–68*) suggested that no two species can occupy the same ecological niche at the same time and place. It is obvious that both *D. sayi* and *D. centroura* occupy the same general habitat and the same food niche in the bay, consequently some degree of competition is suggested. However, competition in a food niche can be determined only when the size of both predator and prey populations are known along with the rates of utilization by the predator populations. Since neither

the sizes of the populations of rays or food species are known for Delaware Bay, competition for food between *D. sayi* and *D. centroura* can only be inferred. There is the possibility, moreover, that sufficient food is available to eliminate competition.

This manuscript is taken in part from a thesis submitted in partial fulfillment for the degree of Master of Science, University of Delaware. Thanks are due Dr. Franklin C. Daiber for suggesting the problem and for his encouragement and criticism. The observations were made possible in part by a National Science Foundation Research Grant, NSF-G4393. Marine Laboratories Contribution No. 14.—Paul W. Hess, *Daystrom Corporation, Poughkeepsie, New York.*

A TECHNIQUE FOR FISH PHOTOGRAPHY.—While conducting a marine biological survey in the Virgin Islands, a successful technique for photographing the colorful fishes of the area has been devised. A fish is brought to the laboratory from the field as rapidly as possible—sometimes alive in a bucket, but usually freshly dead in a small portable ice box. It is laid in a wax-bottomed pan and the fins are pinned in erect position with slender, noncorrosive, insect pins.

Formalin is applied with a fine-bristle brush to the fins including the axillary surface of the pectoral fin. If applied only to the outer surface, this fin may elevate when the fish is placed in water in the photographic tank. Tears in fins may often be repaired by careful pinning. Additional pins and formalin application may be necessary to depress a gill cover, alter the gape of the mouth, straighten the body, etc. Within a few minutes, depending on the size of the specimen, the pins can be removed and the fins will remain in the desired position. Excess mucus is carefully washed from the specimen, and the fish is then placed in a water-tight, glass-bottomed box located over a cut-out section of a plywood table.

The fish is then covered with several inches of water, thus eliminating the surface reflections which result when a wet fish is photographed in air (admittedly fishes can be dried before photographing them, but their life-like qualities may be lost). If the fish tends to float, a slit into the airbladder on the far side and application of pressure to the abdomen will usually expel the gas. It is advisable to perform this in a separate container of water to avoid fouling the water in the photographic tank. A brush is used to sweep dirt particles that do find their way into the tank out of the photographic field.

Photoflood lights are directed on the specimen from the sides of the tank. The camera is placed on a stand built vertically from the table behind the tank. Depending on the location of the lights and other factors a reflection may be seen in the field from the bright metallic surfaces on the front of the camera. This difficulty may be obviated by painting these bright areas with flat black paint or placing a piece of black cardboard in front of the camera with a hole for the lens. A reflection of the photographer's hand when pressing the shutter may appear in the picture. To avoid this, a long cable release or a long stick painted with black paint may be used to trip the shutter. Background is provided by a masonite board painted with flat paint. The board is placed on the floor two to three feet beneath the table. Generally a color is chosen that is complimentary to that of the specimen. For best results the background should be illuminated separately (unless black). The glass bottom of the tank serves to admit background color and eliminate the shadow of the fish.

Charles E. Cutress of the United States National Museum has utilized another method for achieving uniform colored backgrounds without shadow effects. A clear sheet of colored plastic or glass is placed in the bottom of the tank or mounted beneath the tank. Light is directed upward from beneath the tank. A sheet of diffusing glass or plastic is located above the light source to remove "hot spots". The saturation of color in the background can be altered with a change in light intensity. Different colors for the background may be obtained by combining the colored plastic sheets.

Still another method developed by Cutress has the advantage of only requiring light sources from above. A diffusing sheet of plastic or glass and a colored sheet are placed above a mirror and the specimen in turn placed on the colored sheet. Light sources not only illuminate the fish but are reflected upward from the mirror to provide the colored background.

Not infrequently fishes are damaged in their capture or handling and lose scales or are scratched, thus reducing their value as photographic specimens. At times it is possible to replace lost scales from ones on the opposite side. With use of indelible colored pencils, scratches may be touched up directly on a wet fish. If the fish is allowed to dry briefly and placed slowly into the water, a photograph can usually be taken before the color diffuses away.

It may be necessary to alter the direction of floodlights to provide uniform illumination to a large fish. A light meter is useful to test the level of illumination over the surface of the fish.—John E. Randall, *The Marine Laboratory, Uni-*

versity of Miami, Miami 49, Florida. Contribution No. 311 from The Marine Laboratory.

NOTES ON A SECOND RECORD OF *BRANCHIOSTOMA* FROM LOUISIANA.—Hefley and Shoemaker (1952. *Science 115(2976):48*) published the first Louisiana record of *Branchiostoma* from Chandeleur Island, located to the east of the Mississippi River. On the night of March 3, 1959 between 2300 and 2320 hrs. a 19 mm. (T.L.) specimen of *Branchiostoma caribaeum* Sundevall was taken in mid-water tow with a half-meter, No. 10 mesh, plankton net approximately one-half mile south of the Barataria Bay sea buoy. This is roughly 3.5 nautical miles SSE of Grand Isle, Louisiana. Station depth was four fathoms and the calculated depth of tow was 10.4 feet. Observed surface and bottom salinities were 31.6 and 31.9 ‰ at water temperatures of 12.5 and 14.0°C., respectively.

This specimen, now in the collections of the Gulf Coast Research Laboratory, constitutes the first Louisiana record of *Branchiostoma* taken west of the Mississippi River and is apparently the only record between Chandeleur Island, Louisiana and Freeport, Texas (Hoese, 1958. *Publ. Inst. Mar. Sci. 5:315*). The apparent rarity of the lancelet in the Grand Isle area is supported by its absence from a faunal list (1950. Behre, *Occ. Pap. Mar. Lab. La. State Univ. 6:1–66*) covering some 18 years of more or less continuous collections in this region. Mud bottoms predominate and the absence of extensive sandy areas, the preferred habitat of the genus, probably limits the distribution of *Branchiostoma* in this portion of the Louisiana coast.

The present specimen is of further interest in that it was taken in open water of the Gulf of Mexico in a Nansen-type closing plankton net. Bigelow and Farfante (1948. *Sears Found. Mar. Res. 1(1):4*) found no reports on *Branchiostoma* from tow-net samples, but Gunter and Knapp (1951. *Texas J. Sci. 3(1):138*) subsequently reported on four specimens taken in a net streamed from a dock in Aransas Pass, Texas. Since this is a well traveled ship channel and is subject to considerable turbulence and shifting of bottom sediments with the passing of deep laden tankers, it is possible that these specimens were disturbed from the bottom and thrown up into the current and stationary net by the wake of a passing ship. In view of the fact that the Texas tow-net captures are open to question it is considered that the present offshore Louisiana specimen is the first record of the occurrence of an adult *Branchiostoma caribaeum* in a plankton tow.—C. E. Dawson, *Gulf Coast Research Laboratory, Ocean Springs, Mississippi.*

ARTIFICIAL HYBRIDIZATION OF SOME ATHERINID FISHES.—The known examples of natural fish hybridization have recently been listed by Slastenenko (1957, *Publ. Hydrobiol. Res. Inst. Univ. Istanbul, 4 (Fasc. 2–3):76–97*) and the demonstrations of artificial hybridization were discussed in the light of their phyletic relationships by Hubbs and Drewry (1959. *Publ. Inst. Mar. Sci. Univ. Texas, 6:81–91*). Slastenenko listed 212 hybrid combinations of which only 30 are of marine or brackish water fishes.

Two natural hybrids have been reported in the family Atherinidae: *Chirostoma chapalae* Jordan and Snyder X *C. consocium* Jordan and Hubbs (Jordan and Hubbs, 1919. *Stanford Univ. Publ. Univ. Ser. 40:1–87*) and *Menidia menidia* (Linnaeus) X *M. beryllina* (Cope) reported by Gosline (1948, *Evolution 2:306–13*). Hubbs and Drewry also reported an artificially produced hybridization of a *Menidia beryllina* female X *Membras martinica* (Valenciennes) male, the first such intergeneric cross known for atherinids. This cross was repeated in this study.

The purpose of this paper is to report several other artificial intergeneric and interspecific crosses of atherinid fishes. These experiments were conducted at the Chesapeake Biological Laboratory, Solomons, Maryland, during the summer of 1959. The gametes utilized in all the crosses were artificially stripped from the adults; the embryos and larvae were reared in an identical fashion to that described by Rubinoff and Shaw (1960, *Am. Mus. Novitates, No. 1999:1–13*).

Hybridization experiments utilizing three species, *Menidia menidia, M. beryllina,* and *Membras martinica,* in various combinations, provided a wide range of results as indicated in Table 1. In some of the hybrid and control experiments there were examples of total mortality. In most cases the poor survival rates in the hybrids may be attributed to a poor physiological condition of the eggs when the experiments were begun since similar low survival rates were found in the intraspecific cross (control) embryos of *Menidia* and *Membras*. Many of the adult specimens of *Menidia* and *Membras* which were examined during the last two weeks of June and the first week of July had already spawned, indicating that their peak breeding season had already passed by the time these experiments were initiated. Occasionally complete embryonic mortality has also occurred when the gametes were obtained at the height of the breeding season. This unevenness of survival rates may be the result of a combination of factors which were not controlled. For example, the experiments were conducted at room temperature (22–27°C.) which may have fluctuated more than natural environmental conditions. In addi-

TABLE 1.—ARTIFICIAL HYBRIDIZATION OF ATHERINID FISHES

		Began hatching (Days)	Days in hatching	Number of eggs	% Hatched	% Eggs surviving 14 days	% of Hatch surviving 14 days
	INTERGENERIC						
I	*Membras martinica* ♀ X *Menidia menidia* ♂	9	5	689	9	0*	0
II	*Menidia beryllina* ♀ X *Membras martinica* ♂	10	1	—	—	0	0
III	*Menidia menidia* ♀ X *Membras martinica* ♂	7	5	—	—	0	0
	INTERSPECIFIC						
IV	*Menidia beryllina* ♀ X *Menidia menidia* ♂	10	4	388	56	6	12
V	*Menidia beryllina* ♀ X *Menidia menidia* ♂	7	2	—	—	0	0
VI	*Menidia beryllina* ♀ X *Menidia menidia* ♂	10	6	406	86	23	27
	INTRASPECIFIC						
VII	*Membras martinica* ♀ X *Membras martinica* ♂	9	6	644	61	0	0
VIII	*Membras martinica* ♀ X *Membras martinica* ♂	9	3	1029	2	0	0
IX	*Menidia menidia* ♀ X *Menidia menidia* ♂	10	5	148	70	15	22
X	*Menidia menidia* ♀ X *Menidia menidia* ♂	8	3	600	26	2	6
XI	*Menidia beryllina* ♀ X *Menidia beryllina* ♂	12	1	72	17	0	0

* One fish in this group survived 14 days.

tion, there was also the possibility that the somewhat protracted breeding season of these species was maintained by individual variations in the "ripening" process; the uneven results could then be attributed to the experimenter's random selection of individuals in different states of physiological preparedness for breeding.

One fish of an intergeneric combination did begin to feed and survived 14 days after hatching. This fish was, however, lost accidentally before it had transformed sufficiently to determine how it had inherited such striking morphological differences as the keel of scales along the medial fins of *Membras* which are absent in *Menidia*.

Another interesting feature of the development of these fish is the procedure of hatching. Members of the same spawning would hatch over a considerable range of days even though all the siblings had reached the same stage of morphological development prior to the beginning of hatching. There is apparently no correlation between this spread of hatching and conditions such as crowding, since sibling embryos reared in isolation also hatch over a similar extended period. This variation in hatching may be of some survival value to a species which lays eggs in areas frequently exposed at low tides. Under such conditions it would be advantageous to insure some of the embryos hatching at a time which would not lead to their immediate desiccation.

Although hybridization between the genera *Menidia* and *Membras* is experimentally possible and it is likely that the offspring of such crosses could be reared under optimum conditions, it is extremely improbable that such hybrids will be found to occur naturally. These species are separated by rather distinct ecological preferences. Both species of *Menidia* are considerably less pelagic than *Membras*. During this study no specimens of *Membras* were taken in seine hauls. They were usually caught when attracted to a night

light immersed in water. They were taken in 15–20 feet of water while they were swimming toward the light from deeper water.

Appreciation is due Dr. Eugene Cronin for kindly providing the Laboratory facilities at the Chesapeake Biological Laboratory.

This research was supported in part by grants to Dr. E. Shaw from the National Science Foundation (G-4986) and the National Institute of Health (M-2322).—Ira Rubinoff, *The American Museum of National History*. Present Address—*Harvard University, Cambridge, Massachusetts*. Contribution No. 156 Maryland Department of Research and Education, Solomons, Maryland.

Reviews and Comments

PHYLAX TELESCOPUS—VI

It is remarkable how ingrown scientific disciplines may become because of the various factors which foster specialization and limit communication between them. Even though individuals may, from time to time, be exposed to the influence of those in other lines, the specialized nature of the research and the restricted range of the commonly perused journals and books in many laboratories, when added to plain human inertia, usually tend badly to circumscribe the knowledge, thinking, and methodology of the biologists who work in them. This is quite as true in laboratories of such supposedly "general" biological subjects as biochemical genetics or cellular physiology as in those specializing in entomology, plant pathology, or fishery biology.

For example, the marine fishery biologists have for a long time pointed their work chiefly towards a knowledge of the population, its abundance, distribution, and fluctuations, with relatively little attention to the preoccupation of the main body of ecologists with the community as the most important unit to be studied. Now, a few fishery men are beginning to see how narrow and often how sterile such an approach may be without adequate research on the entire community as the prime general source of the fluctuations, abundance and movements of any population within it. At the same time, some terrestrial ecologists (cf. Andrewartha and Birch, "The Distribution and Abundance of Animals," Chicago, 1954) are advocating a radical change in the traditional ecological approach, via the community, to one which emphasizes the dynamics of the populations!!

While it is true that the mere methodology of sampling in the aquatic medium has of necessity occupied a great deal of the thoughts of fishery workers, the types of analysis utilized in estimating the abundance and movements of marine fish populations has reached a high level of refinement. Yet a reader of the book by Andrewartha and Birch (whose research has dealt mostly with insect populations) will find almost no reference to the highly pertinent fish population literature in it, and might easily conclude that the authors either found nothing especially useful in that literature or were not acquainted with it.

The above matters lend force to the growing view that the segregation of fishery, entomological, or "conservation" students or researchers in specialized disciplines, schools, or laboratories, often of a parochial nature and usually divorced in space and thought from more general biological centers and libraries, cannot help but result in a growing narrowness of both thinking and accomplishment.

The present columnist recalls the campaign of the late Aldo Leopold to elevate game management to the status of a separate and respectable profession, with its own professional standards and organization. Game management clearly needed building up, especially on the scientific side, but I am not at all sure that the turn given it by Leopold was an unmixed blessing. Were he alive today, I believe he would shudder at the narrowness of some of his more provincial successors and their teaching, and would agree that the majority of the best men in the field are still trained either in universities where there is no separate management or conservation school, or where such a department has exceedingly close ties and overlapping with the rest of the biological faculty of the institution. This may seem close to heresy to some game managers, just as present-day criticism of "modern education" in the American school system is still stoutly and

sometimes angrily rejected by a large body of the professional "educators" who derived their ideas and methodology either directly or secondarily from the Temple of Modern Education on Morningside Heights subsequent to 1920 or so. Yet every teacher who had experience with education before the newer ideas gained much currency knows that 90% of the high-school graduates of recent years cannot adequately use the English language. The "educators" themselves often cannot, and therefore cannot see what the hullabaloo is about! The result is the most dangerous immediate situation the country has to face, externally or internally!

With any good and useful movement, once it is supplied with a creed, a temple, and an invested priesthood, ideas tend to solidify and the viewpoints of its students to attenuate. Just as the students of any university biological department staffed solely with the adherents of one discipline (be it molecular biology, morphology, or fishery biology) tend to become badly infected with narrowness, intolerance, and *Merulius* spores.

The fishery biologists have attained their narrower professional dignity by a branching road to specialization. Most of the fresh-water men, led for a period by the stream improvers from Michigan and later (in the South) by the pondfish boys from Alabama, jumped on the game-managers' band wagon. The marine and anadromous contingent, weaned from the old "fishculture" days on Gilbert's Fraser River sockeye-salmon methodology and Will Thompson's early California pilchard research, built themselves the Mecca of All True Believers on the shores of Puget Sound—towards which, if we can believe certain impious and possibly envious souls, the anointed, each kneeling upon a Pacific halibut, bow reverently every day at high noon! In any event, the Seattle group, nurtured in a specialized school which has the blessings of the fishery industry and has not always collaborated too closely with other local biologists, long ago staked out the U. S. Fish and Wildlife Service as its private preserve, and (come Democrats, Republicans, or high water) has retained the preserve. I have personally heard two eminent products of this group enunciate the belief that "what's good for the Industry is good for the fisheries." Sometimes I wonder! A good many biologists would say that the men who have, during the past forty years, contributed the most fundamental research and the most original thinking to the problems basic to fish management and conservation have nearly all had their training in England, or Scandinavia, or Canada, or Wisconsin, or Massachusetts, or other less specialized places not hitherto mentioned. And, as with the best of the European sea-fish and freshwater researchers, few of them care to be labelled "fishery biologist" or "fish manager."

* * *

We wish to express our profound respect, hearty congratulations, and deeply felt good wishes to one of our Honorary Foreign Members, who retired at the end of 1960 after long service to the British Museum (Natural History). Dr. Ethelwynn Trewavas, Deputy Keeper of Zoology, began her services to the Museum in 1928, and is well known not only for her earlier collaborative papers with the late Dr. C. T. Regan on bathypelagic fishes, but also for her excellent anatomical contributions on the hyoid and larynx of frogs and toads and the osteology of eels, as well as a large number of important researches on the systematics of the fishes of Africa and the Near East, especially the Cichlidae of the African and Syrian lakes. Equally important has been her largely unrecognized help and advice to innumerable colleagues and to an almost continual stream of students in the Museum's fish department, help which has always been given unstintingly and with the kindly personal concern, quiet dignity, and grace of a very great lady. Few workers have contributed so selflessly and so substantially to their science and few have been so genuinely and generally admired. Characteristically, Dr. Trewavas plans to devote her coming years to laboratory and field work on her two main research projects, the systematics of the African cichlids and the fishes of the Tigris-Euphrates basin. We wish her many happy years with them!

* * *

A large packet of papers published from 1957 to 1960 and recently received from Prof. Robert Mertens, retired Director of the Senckenberg Museum in Frankfurt, has the usual high interest to be expected of the contributions of Europe's most eminent herpetologist. Amongst the papers in *Senckenbergiana Biologica* are three important addenda to Prof. Merten's great monograph of the varanid lizards, one of them on the monitors of Australia (Bd. 39:229–264, pls. 24–31), another listing the monitors of Asia and the East Indian Archipelago (Bd. 40:221–240, pls. 25–29) and a third on the skull of *Varanus flavescens* (Bd. 40:113–115, 2 pls.). There are also papers describing three new Australian lizards (Bd. 39:51–56, 2 pls.), one on the Angolan viper, *Bitis heraldica* (Bd. 39:145–148, 2 pls.), one on the systematics and name of the Ceylonese crocodiles (Bd. 41:267–272), a new *Enhydris* from Sind (Bd.

40:117–120, 1 pl.), and the geographically interesting discovery of a new *Ophisaurus* (*O. wegneri*) in central Sumatra (Bd. 40:109–111, 1 pl.). In another brief article (Zool. Anz., 161:82–85), Prof. Mertens suggests that the "hairs" of the male "hairy frog," *Trichobatrachus*, have a tactile role during amplexus. Finally, in an article included in the book, "Hundert Jahre Evolutionsforschung" (Gustav Fischer, Stuttgart, 1960), Prof. Mertens contributes a discussion entitled (in translation) "From static to dynamic systematics in Zoology," which briefly traces the changing concepts of the taxonomist from the days of Darwin to the present.

In 1952 Dr. Mertens published a small popular field book on the amphibians and reptiles of Central Europe in the series, "Welches Tier ist das?" (What animal is that?) A revised edition of this work (Welches Tier ist das? Kriechtiere und Lurche. 2. Aflage. Stuttgart: Francks'sche Verlagshandlung; 48 pp., 48 pls. 1960; DM 7.20) on much better paper than the first edition, has now come out. The photos, as in all Dr. Mertens' papers, are superb and the 105 text-figures are excellent. This reviewer carried the first edition with him through Europe and found it to be an eminently satisfactory field guide.

* * *

In speaking of field work in Europe, I cannot forbear to mention the pleasure of my first introduction to the European herpetofauna during a few field excursions made in 1960. Listening to the frogs on the Free German side of the Wandsee in Berlin with Dr. and Mrs. Heinz Wermuth; seeking out and finding both newts and a chorus of *Alytes* in the Taunus Mountains near Frankfurt with Dr. Konrad Klemmer (we found a spawning, mated pair, too); patrolling the roads in a car on rainy nights in Holland, Belgium and Bavaria, to find amphibians; and collecting not only *Lacerta*, but also *Bombina*, *Hyla*, and *Pelobates* at the edge of the Hungarian plains near the Neusiedlersee in Austria with Otto Sokol, all were rewarding experiences. But to an American salamander hunter, the carefully manicured forests of Europe are a disappointment. Hard work in the forests and mountains of Bavaria, Switzerland and the Tyrol produced not a single *Salamandra*. Reptiles, too, except for *Lacerta*, were conspicuously absent.

It may also not be out of place to mention some of the research collections visited. The most carefully housed and spotlessly cared for collections of cold-blooded vertebrates that we visited were those at the Musée du Congo Belge in Tervuren (renamed the Musée d'Afrique Central a couple of months after we left) under the care of our very active, productive, and charming colleague Dr. Max Poll. The seeming endless galleries of historic specimens opened to us in Paris by Dr. Jean Guibé and showed to us *in extenso* by Dr. Maurice Blanc, were most impressive, as were the likewise endless vaults of fishes in the basement of the vast museum of Vienna, through which I was piloted by Dr. Paul Kähsbauer. The old Zoological Museum collections on the Invalidenstrasse in East Berlin, in charge of Dr. Kurt Deckert and Dr. Wermuth, have now mostly been brought upstairs and rearranged in immense darkened rooms that were formerly exhibition halls.

The Amsterdam fish collections were just being installed in fine, new, renovated quarters by Mr. Hoedeman. At Leiden, Dr. L. D. Brongersma, formerly the herpetological curator, is the new Director, and greeted us most cordially, while Dr. Boeseman was very helpful with the fishes; the Leiden collections are all in excellent steel cabinets. Dr. L. F. de Beaufort, now retired but actively working on the next volume of "Indo-Australian Fishes," with Mrs. de Beaufort, greeted us cordially at their beautiful home on the heights near Amersfoort. The Senckenberg herpetological collections, in Frankfurt, due to decades of interest and expeditions of Dr. Mertens, are among the finest in the world, but we missed seeing the fish collections and Dr. Klausewitz, who was away. The collections at the Hamburg Zoological Institute, due to be moved before many years into a new building, are not large but are interesting. Prof. Kosswig and Dr. Ladiges greeted us warmly in Hamburg, as did Dr. Erna Mohr, who has recently retired. In Bremen, Mr. Hermann Meinken and Mrs. Meinken gave us the heartiest kind of reception.

We must agree however, that the Europeans who make Americans feel most at home are the Danes. Although two ichthyologists who had greeted us there in 1958 are now gone (Dr. Taaning and Dr. Pfaff), Dr. and Mrs. Anton Bruun, both recovering from serious illnesses, were as charming and interested as ever. Dr. Bertelsen and Dr. Ege at the Marine Biological Laboratory in Charlottenlund Castle (where sorting of the "Dana" Bathypelagic collections still goes on year after year under the eye of Miss Esther Hansen) and Dr. J. Nielsen at the Zoological Museum (also due for a new building in the suburbs) were most cordial. At Lund, Prof. Dahl and Prof. Kauri showed us the Zoological Institute. In Goteborg we missed seeing the retired Director and ichthyologist, Dr. O. Nybelin, but the new Director, Dr. Bengt Hubendick, showed us the newly arranged fish collection.

The Natural History Museum in London, how-

ever, still presents the greatest of all collections of fishes, amphibians, and reptiles. Work on such marvellously rich collections is always a great experience. The London ichthyologists, Dr. Trewavas, Mr. Marshall, Dr. Tucker, Mr. Greenwood, Mr. Palmer, Mr. Wheeler, and others, and the London herpetologists, Mr. Battersby, Miss Grandison, and Dr. Griffiths, are owed a great debt of gratitude by all who visit and do research there.

* * *

A few issues back, we mentioned the 1957 German translation of Nikolsky's Russian text, "Spezielle Fischkunde" (Special Ichthyology). Its companion work on "general" ichthyology is now also available: J. K. Suworow (Suvorov), "Allgemeine Fischkunde" (Deutscher Verlag der Wissenschaften, Berlin: 581 pp., 1959). While Nikolsky's book took up fish classification and groups, the present work deals with fish morphology, "Biologie" (races, ecology, food, breeding, migrations), geographical distribution, ecological grouping, and, finally, phylogeny and paleontology.

The initial chapter, on the history of ichthyology, is, strangely enough, largely systematic in nature, and is useful to an American largely because of its chief weakness—a too-heavy dependence on Russian and German sources. Indeed one suspects that much of the history, insofar as it deals with extra-European ichthyology, was gleaned from Berg, Cuvier, and Jordan's "Guide to the Study of Fishes." In general, the morphological sections seem to be acceptable and reasonably well illustrated, although the pitifully small amount of non-Russian literature quoted is striking. On the other hand, the chapter on age and maturity, which is of special importance in fishery investigations is expanded, with a good deal of western European literature cited. The sections on fish distribution, migrations, and evolution are not particularly strong, at least so far as non-European faunas and sources are concerned. Despite all this, there is no modern text of this type in English!

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As the manuscript of this column goes to the Editor, Dr. Earl S. Herald's well done and beautifully illustrated "Living Fishes of the World" (Garden City, N. Y.: Doubleday and Co.; 304 pp., 300 photos, 145 of them in color; $12.50) has just been published. We congratulate the author on a job well done and trust that a formal review will soon be published.—GEORGE S. MYERS, *Stanford*, 9 March, 1961.

THE FISHES OF THE FAMILY SEARSIDAE. By A. E. Parr. 'Dana' Report 51, published by the Carlsberg Foundation, Copenhagen, 1960; 109 pp., 73 figures in the text.—This work is a systematic monograph of a deep-sea family of uncommon isospondylous fishes separable from the Alepocephalidae by a single character: the presence of "a large, round sac located immediately inside of the upper portion of the cleithrum." This family, together with two of the three component subfamilies, was established by Parr in 1951.

Parr first outlines his procedure for measuring specimens, an account of taxonomically useful characters, and a well-illustrated discussion of differences in form and of allometric growth in these fishes. The classification itself begins on page 23 with a discussion of the family and subfamilies, and proceeds through 12 genera and 20 species or subspecies. Clear and bold figures of each described form and anatomical details of taxonomic or biological interest accompany each description, and his morphometric data are graphically presented in an admirable way. If one is acquainted with Parr's method of separating genera and species by simple although infrequently used arithmetical expressions, most of the keys should be as adequate as the material on which they were based permitted. The paper closes with a list of the DANA specimens included in the report and a bibliography which includes works on both the Searsidae and the Alepocephalidae.

To this reviewer, Parr's Searsidae is an example of ichthyological research properly done and excellently reported. Absent is the extraneous matter which disguises the important features in some authors' accounts; absent as well is the ambiguity of expression too commonly encountered elsewhere. Some will disagree with Parr's methodology or classification, but none is likely to misinterpret his writing. This reviewer would like to have seen included at least summary statements of distribution, habitat and reproduction: Are the searsids benthonic or bathypelagic? Can a reason be proposed for the apparent absence of searsids from the Sargasso Sea, an area in which the DANA has worked intensively? What of the larvae? Are we to assume that none were caught by the DANA? This would be of extraordinary interest if the searsids are truly bathypelagic as the capture of adults by the DANA's midwater nets would suggest. But I am too appreciative of that which is included to be critical of that which is not. This is a fine systematic revision, excellently prepared, and printed in the manner to which those who have

followed the 'Dana' Reports have long been accustomed.

Those unfamiliar with Parr's approach to morphometric analysis may be confused by his graphs, with which he demonstrates changes in the dimension of one part relative to the whole, and a detailed discussion of this method, elucidated in earlier papers, has not been repeated in this report. The body part, expressed as a per cent of body length, forms the ordinate; the body length the abscissa. The relationship ($100\ y/x = a + bx + cx^2 \cdots$) stands in contrast to the usual rectilinear regression ($y = a + bx$). Parr's use of this modification with its derived complexities as a practical taxonomic device was once criticized in terms inappropriately derisive but later, in connection with its application to larval differentiation and metamorphosis, in a form scientifically and semantically more appropriate. And in this exchange, Dr. Parr has fared as well as his adversaries. The statistical and practical questions involved here are beyond the scope of this review, but for those to whom Parr's graphs are unclear, I recommend his recent paper (1960, *Americal Museum Novitates No. 2019, 13 p.*) and his earlier papers on methodology referred to therein.

Once again credit is due the Carlsberg Foundation and those who have managed the collections of the present DANA and her predecessors. To these Danes the collections of an expedition are a thing of enduring importance, to be meticulously and patiently sorted and labeled and, sooner or later, put into competent hands for study. By American standards, the expeditions have been few, but by any standard the results have been immense. Exclusive of preliminary papers, the ensuing quarto DANA reports cover a four-foot shelf in our library. This approach to marine zoology is also clearly evident in recent Soviet marine biological research, but in the U.S., except for a few programs geographically restricted, such collections do not exist and are not now being assembled. The last comprehensive American treatise on deep-sea fishes which was world-wide in scope and based principally on the results of U.S. expeditions appeared in 1895. Neither Parr's Scarsidae, nor any comparable deep-sea study, could now be prepared from the study of American collections.

It has been 20 years since the DANA collection of alepocephalid fishes came to Parr for study. During the intervening period, Dr. Parr, by desire and demand, has spread his attention among an array of interests from physical oceanography to the directorship of one of this country's few great museums. During these years his studies of alepocephalids and scarsids have followed the pattern unfortunately too common: the publication of preliminary papers; terse, sometimes inadequately clear, and largely unillustrated but containing the new names and classification intended to serve as a skeleton for the monograph to follow. Those of us who tried to study alepocephalid fishes with these papers were unhappy. The prognosis was the usual one—that of the man whose monograph was interrupted for cause: administrative responsibility, retirement, or loss of interest. We are then left with the ichthyological residue, such as the series of Chabanaud papers on soles and the uncompleted Ginsburg "Revision of the American Gobiidae".

But Parr's completion of the Searsidae section of the alepocephalid-like fishes is evidence of his desire and ability to complete the work on the Alepocephalidae proper. We have waited twenty years for the Searsidae; I hope that nothing will divert the interest of Dr. Parr from the fulfillment of his intent: a similar monograph of the Alepocephalidae. And may it be as excellent as his "Fishes of the Family Searsidae".—GILES W. MEAD, *Museum of Comparative Zoology, Harvard University.*

A GUIDE BOOK TO THE MARINE FISHES OF RHODE ISLAND. By Bernard L. Gordon. The Book & Tackle Shop, Watch Hill, Rhode Island, 1960. vi + 136, 77 photo. Cloth. $4.00.—Attractive and copiously illustrated, this well-printed book will be welcomed eagerly by some fishermen and amateur naturalists but with mixed emotions by most ichthyologists and fishery biologists, to whom it is of little use. Heralded as the first comprehensive guidebook to the 215 species of salt-water fishes found in Rhode Island waters, based on a five-year survey, it is nothing more than a slightly expanded check-list, greatly augmented by some 30 pages of very good photographs of 62 species by the author.

The book contains a brief introduction, a history of Rhode Island ichthyology, the background to the Rhode Island ichthyological survey, trends in fish populations (largely a potpourri discussion of the commercial and sport fishery, listing 40 "new" species over those recorded by Henry C. Tracy in 1910, and effects of hydrography on the distribution of fishes), and the long list of brief annotations of the fishes. Most of these sections are so brief or general as to be uninformative, although the five-page bibliography will prove useful to beginning investigators in the region. It should be noted that Tracy published seven important papers on the fishes of Rhode Island, all in the Annual Reports of the Rhode Island Commission of Inland Fisheries, and they should be added to the

single reference by Tracy. The annotated checklist for each species is divided into scientific name, common names, brief statement of occurrence, and economic importance. It is unfortunate that very little new ecological, taxonomic or biological data is given for most of the species.

Since the book is carelessly edited and filled with errors of several types, it can prove a hindrance to the serious novice. At least 25 misspellings of scientific names were discovered during the first perusal of the book. Furthermore, the scientific names of many species have been long out-of-date, which could have been ameliorated had a copy of "A list of common and scientific names of fishes from the United States and Canada" been available. The author also showed little knowledge of taxonomic literature. For example, in his bibliography he cited Nichols and Breder (1927. *Zoologica 9(1):106–17*) who correctly identified the European species of the scad or saurel, *Trachurus trachurus* (listed as such on p. 55 in Gordon), from Newport, Rhode Island, as *T. lathami*. Merriman (1943. *Copeia (4):205–6*), Ginsburg (1952. *Univ. Tex. Publ. Inst. Mar. Sci. 2(2):205–6*), and others have upheld this identification, although the fact that Bigelow and Schroeder (1953. *U. S. Fish & Wildl. Serv. Bull. 53(74):377*), which Gordon apparently used as a primary reference, acknowledged but did not adopt the name *T. lathami* could have steered the author off the proper course.

This book is a typical example of a regional work that was zealously but uncritically compiled. The author plans to issue a second edition. If so, the revised work should be carefully edited and reviewed by competent ichthyologists of his region, and should embody much more original data on the biology of each species.—ROMEO J. MANSUETI, *Chesapeake Biological Laboratory, Solomons, Maryland.*

STUDIES ON THE RAJID FISHES (RAJIDAE) FOUND IN THE WATERS AROUND JAPAN. By Reizo Ishiyama. Journal of the Shimonoseki College of Fisheries. 1958. 27(2):189–394. 86 Figures and 3 Plates.—This study of the Japanese skates by Ishiyama represents an expansion and a review of his earlier investigations of these batoids. There are three main parts to the study; comparative anatomy, ecological and geographical reconnaissance, and taxonomy.

Ishiyama devotes over half of the text to describing and evaluating various morphological materials in terms of phylogenetic relationships. Much of this particular section is concerned with the male clasper. The various components of the external and internal anatomy, such as pseudosiphon, spur, claw, axial cartilage and ventral terminal, are described. Ishiyama recognized two major categories of Japanese rajids, a northern and a southern group. The northern group consists of two genera, *Rhinoraja* with three and *Breviraja* with nine species. The genus *Raja* makes up the southern group with 11 species. Based on the presence or absence of various external and internal features Ishiyama recognized seven clasper subtypes among the northern forms and six within the southern group. These various structures and types are described and illustrated in numerous line drawings. Ishiyama suggests a phylogenetic interrelationship among the various Japanese rajids and between the families Rajidae, Platyrhinidae and Rhinobatidae based on the clasper and its associated apparatus, and the number of precaudal vertebrae among the rajids. He is convinced the clasper and associated structures are a strong taxonomic tool with specific distinctions. In two species Ishiyama was able to distinguish subspecific differences in this organ. A key has been provided for recognizing structures is a strong taxonomic tool with spe-

The discussion of the egg cases is a summary of an earlier work (1958. *Bull. Mus. Comp. Zool. 118(1):1–22*). Twenty-two species have been separated into a northern and a southern group with four case types within each group. These types are distinguished by case shape, horn size, tendrils, surface configuration and the histological structure of the capsule wall. The egg case had not been observed for the twenty-third species, one that belongs to the northern group.

Ishiyama considers the nature of the egg capsule to be of phylogenetic value similar to that depicted by the claspers. However, he considers that environmental influences prevent an exactly parallel interpretation. He goes on to say that there are two ways for establishing a taxonomic category for a species, one to use the most reliable character and secondly to use several characters with limited variability. The author thinks he is well justified in his use of the male clasper as the most diagnostic feature available for the Japanese rajids

The snout and associated structures are of limited phylogenetic importance, at best to the subgeneric level. This is evident in the key that was constructed for this particular character; species cannot always be separated. The shape and position of the anterior fontanelle may be of importance for the two genera of the northern group, *Rhinoraja* and *Breviraja*.

Characteristics of the tail provide another means for Ishiyama to separate the Japanese skates into a northern and a southern group. The characters that appear to be of taxonomic

importance are tail shape, relative length, and structural character of the electric organ. The northern group is characterized by a short electric organ located near the tip of the tail with cup-form elements, and a relatively sparse spination. The southern group possesses an electric organ with disc-form elements occupying most of the tail length, and a dense spination. Ishiyama thinks there is a marked similarity in the interrelationships displayed by the tail characters and the claspers.

There follows a discussion of the function of the tail among these batoid fishes. The original function is locomotion. This may be decreasing in importance as there appears to be an inverse relation between tail size and pectoral fin size. A second function may be defense. However, the weak discharge from the electric organ raises a question about the importance of this defensive mechanism. Ishiyama proposes a third function, that of orientation, particularly associated with the benthic habits of these animals.

The numbers of vertebrae, intestinal valves, heart valves, and the placoid scale characteristics are evaluated. In general they are of only limited value, separating the southern genus *Raja* from the two northern genera. Color and pattern differences do not fare well as taxonomic characters since there is just too much variation.

The section dealing with age and growth is in part a review of previous work done by the author on two species of *Raja* and an extension of his work to a third species. Apparently all three are of economic importance in the Japanese fishery. The technique is based on the sectioning and staining of the vertebral centra. There is a discussion pertaining to the selection of the proper vertebrae, the relationship between vertebrae and fish size and when the growth rings are formed. The rates of growth are calculated for one species. The oldest specimen was in its sixth growing season. This is comparable to our east coast form, *Raja eglanteria*.

The two forms of skates comprise a shallow warm water southern group and a deep water or arctic northern group. The distribution of these two forms overlap for the most part along the coasts of Honshû, the main Japanese island. The distribution of the southern group seems to be associated with the warm Kuroshio current, while the northern two genera are found within the pattern of the cold Oyashio and Liman currents.

The remainder of the monograph is devoted to taxonomic descriptions. Of the three genera comprising the rajid fauna of Japan the genus *Rhinoraja* is endemic to the area under study. The other two are more cosmopolitan, found in the Atlantic as well as other areas of the Pacific. Ishiyama uses the characters he has evaluated in the earlier section to designate the various taxonomic levels. As a result he erects three new subgenera *Notoraja, Bathyraja* and *Arctoraja* comprising the genus *Breviraja*. There is only one species within the subgenus *Notoraja*. Six species make up the subgenus *Bathyraja*, one of which is described as a new species. Two species comprise the subgenus *Arctoraja* and Ishiyama erects a new subspecies for one of these.

The author thinks the endemic genus *Rhinoraja* may have been derived from an ancestral form resembling the genus *Breviraja* but considers some features of the *Rhinoraja* to be much more specialized. Three species are recognized, one of which is newly described.

The southern genus *Raja* is divided into two subgenera *Okamejei* and *Tengujei*. The former consists of seven species, three of which are newly described. One of the older species is divided into two subspecies. The subgenus *Tengujei* consists of four species, one being newly erected.

Ishiyama has presented his interpretation of the morphological structures used as taxonomic criteria, treating each more or less separately and using the most reliable character. However, the reviewer wishes Ishiyama would have made an attempt to integrate the use of these various structures in his phylogenetic portrayal of the skates and the subsequent development of a taxonomic key for separating species. The usefulness of a number of keys is reduced by the specific treatment employed. It has been the reviewer's experience that, while it is desirable to have one very reliable character, it is frequently necessary to have available several secondary criteria for distinguishing species.

Continued oceanographic exploration, and examination of material collected outside the area of this study will determine the validity of some of Ishiyama's interpretations. Whatever the outcome may be this monograph will be important in any further investigations of the rajid fishes. It will stand as a good example of how the taxonomist sets up criteria for a particular group, evaluates the validity of these characters and then proceeds to use them.—FRANKLIN C. DAIBER, *Marine Laboratories, University of Delaware, Newark.*

REPTILIA. *Zoological Record*, Vol. 94, Sect. 16 B, 1957: 94 pp. Compiled by J. C. Battersby (Recent) and W. E. Swinton (Fossil). Zool. Soc. London, 1960. Seven shillings and sixpence.—The general usefulness of the *Zoological Record* has been favorably remarked upon in an earlier review of the 1956 section on Amphibia (see

Copeia 1960: 163–164). While the present section is quite likely useful, some comments on coverage and treatment seem called for.

There are approximately 650 titles listed by author and cross-referenced in subject indexes. Upon eliminating reviews, obituaries, nomenclatorial proposals and counterproposals, abstracts, and about 115 popular articles from the total there remain some 500 papers and books as contributions to knowledge. Two-thirds of this number are in English; the other principal languages are German, French, and Russian. More than half the Russian papers were on paleontological material and in number (20) they match those in English. As in the Amphibia section referred to above, a lag in coverage was evident: 10 per cent of the papers listed were published before 1957, chiefly in 1956.

Comparison of coverage for 1957 in this *Zoological Record* section and in *Biological Abstracts* through 1958 revealed the pattern found previously: *Biological Abstracts* listed substantially fewer papers and was very weak in non-English titles. Again, however, excluding the titles from *Copeia* and *Herpetologica*, about 30 per cent of the papers listed by *Biological Abstracts* are not in the *Zoological Record*.

A sampling of the missed includes papers on turtle shell abnormalities (*Fieldiana. Geology*), alligator metabolism experiments (*Am. J. Physiol.*), parasites of *Calotes* (*Ann. & Mag. Nat. Hist.*), Triassic reptile footprint faunules (*Bull. Mus. Comp. Zool.*), a turtle subspecies new to the U. S. fauna (*Proc. Biol. Soc. Wash.*), jaw foramina of dinosaurs (*Contrib. Roy. Ontario Mus.*), and turtle blood characteristics (*Am. Midland Naturalist*). No doubt some of the missed papers will be listed in future sections of the *Record*. Still there seems to be evidence that a fair number will not be noticed soon unless a special effort is made to do so. This is adduced from the following examples of articles which escaped listing in 1956 and in 1957: a paper by Srivastava on the urogenital anatomy of male *Python* (*J. Anat. Soc. India*), one by Leroy on sexual differentiation of Mullerian ducts in *Chamaeleo* (*Arch. Soc. India*), one by Leroy on sexual differentiation of Mullerian ducts in *Chamaeleo* (*Arch. Biol.*), and another by Nemtsov on comparison of actions of cobra and viper venoms (*Doklady Akad. Nauk. SSSR and* subsequently in *Referat. Zhur., Biol.*, 1957). When it is remembered that these checks were made through use of an inferior abstracting journal, relatively complete retrieval of herpetological literature seems a rather distant prospect.

No thorough examination of the subject index parts of the section was made. However, improved treatment in cross-referencing seems possible. For instance, a paper on "Jugendentwicklung von *Uromastyx acanthinurus*" is listed under the category ECOLOGY AND HABITS but not under REPRODUCTION AND SEX or under DEVELOPMENT. Another on the development of the mid-brain and position of the forebrain in agamids is listed under the subcategory Sense Organs but not under Nervous System. A particularly poorly handled paper is Underwood's critique of McDowell and Bogert's work on *Lanthanotus* and the anguimorph lizards. The critique is listed only under Reviews and *Lanthanotus* although it contains original material and important comments on the morphology and the relationships of several lizard and snake genera. Other inadequate indexing was evident in the systematic section. Thus a new Mexican *Thamnophis* described by F. G. Thompson is listed but the following actions in his paper were overlooked: designation of a lectotype of *Thamnophis angustirostris* (Kennicott), relegation of this form to the synonymy of *T. marcianus*, and allocation of most post-1908 references on *T. angustirostris* to *T. rufipunctatus*. Similarly, the *Record* failed to note the restriction of *Emys* to *orbicularis* and the removal of the American species *blandingi* to *Emydoidea* by Loveridge and Williams in their work on African cryptodires. Perhaps these deficiencies loom relatively large in my mind because of the *Record*'s assiduous indexing of general books, which account for many of the individual systematic references.

My purpose in making the specific criticisms above is to indicate that the papers omitted or poorly cross-referenced are in fact ones that should not be so ignored. I am, of course, appreciative, as are most workers, of the time and energy that the compilers devote to this valuable bibliographic tool. Nevertheless, the need for improvement of the *Record* is obvious, especially in view of the continuing expansion of the biological literature. Once more I urge that readers help by seeing that their papers and those of their colleagues reach the editor of the *Record*.—GEORGE B. RABB, *Chicago Zoological Park, Brookfield, Illinois.*

DIE SAURIA DES GRAN CHACO UND SEINER RANDGEBIETE. (The lizards of the Gran Chaco and its periphery). By Walter Hellmich, Bayerische Akademie der Wissenschaften, mathematische-naturwissenschaftliche Klasse, Abhandlungen, Neue Folge, 1960: Heft 101, 131 pp., 1 map, 2 plates. (No price listed).—The title of this study is mis-leading as it represents a report on a single collection with very limited

use of other materials. The report forms the second part of the herpetological results of H. Krieg's Gran Chaco Expeditions. The first section, written by Müller and Hellmich (Stuttgart, 1936, 120 p.), covered the frogs, turtles and crocodilians. Most of the stock was unfortunately destroyed by fire. The present report deals with a composite collection of lizards, including material from other journeys. Hellmich had 688 specimens of 42 species, and added brief diagnoses of another 43 species from the literature.

The collection included only three new forms. These had been published previously and are here illustrated for the first time, in the only figures of the report. For most species there is a partial synonymy, a list of localities, an often lengthy description of one individual, and a discussion of variation observed within the series (often including taxonomic remarks). Little life history data is offered. The report concludes with brief sections on general ecology, zoogeography and the evolution of the fauna.

The citation of literature is far from complete. While locality records from beyond the Paraguayan region were justifiably omitted there is, for instance, little excuse for not citing Vanzolini's 1955 study of *Amphisbaena alba*. This kind of omission may only be justified in a straight descriptive listing of forms. Its inclusion would have obviated a discussion whether *A. alba* and *camura* are separate species.

More distressing is the fact that important conclusions of papers cited in the bibliography have unaccountably been omitted from the text. For instance under *Amphisbaena vermicularis* there is no mention of Vanzolini's 1949 critique of Amaral's 1935 and 1937 papers. Vanzolini 1949 is listed in the bibliography, but only Amaral's views are presented.

Since the Munich Museum has apparently saved a number of Wagler's original types of wide ranging forms that enter the Gran Chaco, it would have been more useful to include a brief redescription than to repeat the 1882 opinions of Strauch.

The reviewer's most serious complaint arises from the attempt to make this more than a useful collection report by the addition of scarcely documented discussions. Trip reports on collections from poorly known regions are valuable. The inclusion of references to those forms that might have been encountered increases their utility. However, the South American herpetofauna stands in dire need of revisions on the specific and generic level; in some groups assignment to species is not yet possible without it. Such work requires more than the material of a single collection or museum; an analysis of an entire fauna will inevitably require the collaboration of specialists. Zoogeographical conclusions derived from a study not preceded by revisionary work hardly rise above the level of speculation.—CARL GANS, *Department of Biology, The University of Buffalo, Buffalo 14, New York.*

DIE AMPHIBIEN UND REPTILIEN EUROPAS (Dritte Liste, nach dem Stand vom 1. Januar 1960). By Robert Mertens and Heinz Wermuth. Waldemar Kramer, Frankfurt am Main, 1960, xi + 264 pp., 43 figs.—For more than three decades less provincial-minded American herpetologists and zoögeographers have depended largely upon the work of Robert Mertens and his collaborators for an authoritative summary of the systematics and distributions of European amphibians and reptiles. Earlier editions of the checklist, published in 1928 and 1940, were prepared by Mertens and the late Lorenz Müller. The 1960 revision, the first to be published in book form, has been prepared by Mertens and Heinz Wermuth, whose check list of the turtles, crocodilians, and rynchocephalians of the world published in 1955 should now be familiar to herpetologists.

This third edition of *Die Amphibien und Reptilien Europas* is more than a check list, however. It provides illustrated keys to the orders, families, genera, and species native to Europe, including the marine turtles that occasionally reach the shores of the continent. Subspecies can be identified in terms of the ranges defined for each. Keys are avowedly designed for the layman rather than for the specialist, who would often prefer to employ characters of greater fundamental importance to classification than the external characters that more readily serve the needs of the amateur. The addition of keys, with the numerous figures to illustrate them, doubtless broadens the usefulness of the check list, without detracting from its value to the professional herpetologist.

Continuing the practice employed in the introduction to the second edition, Mertens and Wermuth list the numerous taxonomic changes proposed during the last two decades, employing more than a dozen categories to summarize such information. These summaries are followed by a tabular comparison of the numbers of families, genera, species, and subspecies recognized in the three editions.

Perspective is added by a brief account of the modifications systematists have introduced into the classification of European amphibians and reptiles since the publication of the 1758 edition of *Systema Naturae*. Of the 20 species Linnaeus described, six proved to be synonyms. In addition

to the 14 species that proved to be valid, Linnaeus applied names to 15 others outside the continent that have since been taken in Europe. As an index to the refinements in our knowledge of distributions as well as of species concepts, it is of historical interest to note that Mertens and Wermuth now list 150 species where Linnaeus recognized but 29 for the whole of Europe two centuries ago.

The continuous shifting of political boundaries in Europe is a handicap to anyone dealing with the distributions of animals. With no assurance that political boundaries will remain fixed, Mertens and Wermuth perhaps considered it unprofitable to provide tabulations of the species known to occur in each country. In lieu of this, and in view of the uncertainties that prevail as far as international boundaries are concerned, distributional maps would have been a welcome addition. Maps of the sort are available in some of the recent handbooks, notably Ion E. Fuhn's account of the amphibian fauna of Romania, published in 1960, but since Günther Hecht (1928, *Mitt. Zool. Mus. Berlin 14:503–595*) mapped the distributions of the reptiles inhabiting northern Europe, few authors dealing with the fauna of Europe have bothered to map the distributions of species native to their country much less depict the ranges of those with distributions extending beyond the confines of the continent.

The task of mapping the distributions of 150 species would have been both tedious and time-consuming, even with the subspecies omitted. Relatively few valid species have been described since the edition of 1928, when 134, with races totalling 250, were listed. With additions offset by deletions or the relegation to subspecific status of forms listed earlier, the list of species has increased by only 16. In contrast subspecies have been added at a rate approximating nearly one hundred for each decade, with 445 listed in the third edition. A large percentage of these races belong to one genus, *Lacerta*, for which 30 species are now listed for Europe with a total of 201 races if the nominate subspecies are included. Moreover, 66 of these names have been proposed since 1940. One species, *Lacerta sicula*, is regarded as being comprised of no fewer than 39 races. Plainly the taxonomic situation in this genus is becoming as confused as that created for North American pocket gophers by those mammalogists who feel impelled to apply names to virtually every local population.

One can scarcely doubt that several species of *Lacerta* are extremely plastic, with discernible morphological differences reflecting the adaptations of individual populations to restricted environments. Mertens and Wermuth observe that taxonomists find it easier to apply names than to provide detailed analyses of the variations encountered, a comment equally applicable to much of the work done on lizards of the genus *Cnemidophorus* in North America. The complexities and uncertainties encountered in studies of lacertids are reflected in the shifting of races from one species to another, for six changes of the sort have proved to be necessary since 1940. Mertens and Wermuth doubt that quite so many races in *Lacerta* are justified, and admonish their colleagues to realize that no two populations are likely to be identical. Though it is true that a population occupying a few square yards on a Mediterranean island may be sufficiently well differentiated to warrant nomenclatorial recognition, they pointedly add that systematists should proceed with caution and refrain from applying new names indiscriminately.

Apropos of this discussion, it is but mildly impertinent to note that *Gymnodactylus kotschyi stepaneki* was described by Wettstein the same year that *G. k. wettsteini* was described by Stěpánek.

The majority of the species added to the European list since 1940 are attributed to a reconsideration of the boundary between Asia and Europe. The outline map provided shows the generally accepted boundary found in most modern atlases, with the line between the continents drawn along the crest of the Ural Mountains and extending southward through the northwestern portion of the Caspian Sea to the spit that extends eastward from the Caucasus, the crest of which separates Europe from Asia Minor.

A few Asiatic species omitted from earlier editions are now known to have distributions extending north of the Caucasus, as mapped by Terentjev and Chernov in their *Encyclopedia of Reptiles and Amphibians* [of the Soviet Union] published in Moscow in 1949. These include two frogs, *Pelodytes caucasicus* and *Rana camerani*, three lizards, *Gymnodactylus russowii*, *Agama caucasica*, and *Lacerta derjugini*, and three snakes, *Eirenis collaris*, *Elaphe hohenackeri*, and *Vipera kaznokovi*, all of which were described prior to the turn of the century. Terentjev and Chernov also indicate a distribution for *Coluber ravergieri* extending well north of the Caucasus, but this species is considered verified for Europe by Mertens and Wermuth.

These authors delete *Blanus strauchi*, one of the two amphisbaenids previously listed for Europe, because they cannot confirm its occurrence on the continent. The lacertid, *Algyroides marchi*, from the Sierra Cazorla in southeastern Spain, described by Valverde in 1958, is the only full species previously unrecognized that ap-

pears in the third edition. Six forms listed in earlier editions as species are now relegated to subspecific status. Inevitably a few names for both species and subspecies have been replaced by earlier names unearthed in the literature. Mertens and Wermuth sensibly list ten other names more widely used over the years, with the request that the International Commission add them to the list of *nomina conservanda*, despite their preoccupation by earlier names. A similar request is made for fourteen additional names in use despite their illegitimate origins as quadrinomials or "varieties" before such categories were outlawed by the Rules as having no official status.

In a departure from the practice in earlier editions, Mertens and Wermuth employ the names of the higher categories from the Class to the Family as headings without designating levels or citing authors. They arrange these categories systematically, but list genera, species, and subspecies alphabetically under the respective family headings, with synonyms, arranged chronologically, cited only for species and subspecies. They dispense with subgenera, but supply German vernacular names for the animals in each group, from the Class to the species level, and refrain from applying common names to subspecies. Like K. P. Schmidt, in the sixth edition of the North American check list, Mertens and Wermuth employ Caudata and Salientia, rather than Urodela and Anura at the ordinal level, as advocated by Romer, who reserves the name Salientia for a Superorder that includes the Anura.

Doubt concerning the affinities of the Typhlopidae with the snakes continues to mount (see Robb, 1960, *Australian Journ. Zool. 8:181–216*), but at this juncture Mertens and Wermuth can scarcely be criticized for continuing to list the "blind snakes" under Serpentes. Zangerl (1944, *Am. Midland Nat. 31:417–454*) once advanced arguments for placing the amphisbaenids in a separate order, but later recommended placing them *incertae sedis* under the Squamata, where other authors have listed them as a separate Suborder of equal rank with the Sauria. Mertens and Wermuth leave the Amphisbaenidae with the lizards.

They use trinomials to designate closely allied forms as members of polytypic species, a procedure eminently preferable to assigning specific status to every disjunct population slightly differentiated morphologically, whether it be insular or isolated ecologically and geographically. Nevertheless, it is possible to be over-zealous in applying the "Rassenkreise" principle. Several recent investigations of morphologically similar Anura reveal disjunct populations to be genetically incompatible. The use of trinomials is surely open to question when detailed information concerning distributions discloses narrow zones of overlap where both forms occur side by side in the same habitat with no evidence of interbreeding.

Genetic discontinuity may result from divergence in breeding seasons, mating behavior (including the mating calls of the Anura), or in other attributes defined as ethological, even though two species may be morphologically similar and genetically compatible. Occupancy of ranges almost wholly separate, or the occasional occurrence of hybrids in restricted areas of contact are not sufficient grounds *per se* for ranking such populations as subspecies.

Perhaps on the assumption that the populations are allopatric, Mertens and Wermuth regard *Hyla meridionalis* as a subspecies of *Hyla arborea*. The trinomial employed in this instance has untenable implications in view of the information H. W. Parker (1956, *Systematics Assoc. Pub. (2):9–15*) supplies. Parker maps the distributions of both *arborea* and *meridionalis*, indicating an extensive zone of overlap in their distributions. Where they occur sympatrically they do not interbreed. Spectrographic analysis of their mating calls, which I have discussed in greater detail in the A.I.B.S. symposium on *Animal Sounds and Communication*, reveals differences of sufficient magnitude to confirm Parker's belief that *meridionalis* should be regarded as a distinct species, with a race of its own. Whether Mertens and Wermuth do not concur with Parker or merely overlooked his paper, there can be little doubt that *H. arborea* and *H. meridionalis* have reached the species level in their divergence, which presumably dates from an earlier isolation. It remains to be shown whether the two are genetically compatible, as they may be, despite an array of isolation mechanisms that prevents interbreeding in the zone of sympatry.

How useful are check lists? Their use by systematists depends largely upon the thought and effort such authors as Mertens and Wermuth devote to ferreting out synonyms and delineating distributions. The need for a check list of North American amphibians and reptiles evidently diminished with the advent of one or more handbooks that cover each of the major groups inhabiting the United States or both amphibians and reptiles in portions of the United States and Canada. Systematists dealing with larger faunal areas often find that check lists, if kept up to date, are more useful than handbooks, few of

which are revised. Moreover few handbooks attempt to list synonyms, and though check lists are rarely as exhaustive as monographs of genera in this respect, they provide a means of summarizing the results of such investigations. As such they deal primarily with classifications and nomenclatorial problems, matters of immense importance to the specialist.

Aside from their use by systematists, check lists provide a ready means of comparing faunas. It is of interest, for example, to note that, with additions since the 1953 edition of the North American check list, we can report more than 400 species of amphibians and reptiles for continental United States, in contrast to 151 for Europe. The smaller herpetofauna of Europe has been attributed to the mountain chains stretching from east to west. These, it is assumed, were barriers to post-glacial dispersals of species believed to have retreated southward when colder climates prevailed.

One can scarcely doubt that climatic changes have been responsible for extensive shifts in faunas and floras, and perhaps the distributions of the terrestrial ectotherms have been more drastically affected than those of birds and mammals. It is questionable, nevertheless, whether the mountain chains of southern Europe have been of vast importance in limiting dispersals from the south. Were physiographical barriers so formidable it would be difficult to explain why many reptiles are widely distributed north of the Pyrenees, the Alps, and the Caucasus. Such species as *Vipera berus* and *Lacerta vivipara*, with distributions extending into northern Europe beyond the Arctic Circle, do not necessarily tolerate lower body temperatures, or remain active at thermal levels below those of species in warmer climates. But specializations in their physiology, modes of reproduction, and other adaptive modifications were doubtless prerequisites for survival in areas where their activities are restricted to a few months of the year.

If one assumes, however, that the tolerance of short growing seasons enabled these reptiles to cross the mountain barriers, one must further assume either that some species were preadapted for temperate zone habitats, or that they could not penetrate the regions north of the supposed barriers until their peripheral populations were subjected to selective modifications as they slowly extended their ranges to higher elevations in the mountains.

In essence, therefore, these assumptions imply that restricted northward dispersals of many species depend not so much upon physiographic barriers *per se*, as upon limitations in the adaptability of such species to the shorter growing seasons encountered in latitudes farther from the tropics. In some respects it is more difficult to account for the distributions of amphibians and reptiles restricted to temperate regions. *Vipera berus*, for example, has a range that extends from the British Isles across Europe and Asia to Sakhalin Island. But to the south the distribution of this viper barely extends into northern Spain and Italy, or approximately the latitude of Boston. Like some toads and frogs, *Vipera berus* is seemingly specialized for life in moist temperate regions, but ill adapted for existence in the warmer, more arid habitats to the south.

The dubious importance of mountains as barriers is evident from other data. Terentjev and Chernov (*supra cit.*) indicate the presence in Europe of several species with distributions extending northward beyond the Caucasus but not into the Ukraine. Latitude, moreover, is evidently more important than *Lebensraum* in limiting the number of species. Terentjev and Chernov record only 158 species, 33 amphibians and 125 reptiles, for the U.S.S.R., or only seven more than are now known for Europe at much the same latitude but with a total area half the size. The U.S.S.R. with fewer species of *Vipera* than Europe, extends southward into areas inhabited by *Echis* and *Pseudocerastes* in addition to one member of the Elapidae, *Naja oxiana*. Elapids, though no longer represented in Europe, inhabited France during the Miocene. The presence of cobras in Europe millions of years ago is probably indicative of warmer climates at the time. It is far from certain that elapids are no longer represented in Europe because they failed to cross montane barriers following the last recession of the ice sheet.

Meager or not, the amphibian and reptile faunas of Europe are interesting, partly because they have been studied in greater detail than those of any other continent. Professor Mertens, whose travels and investigations have taken him to many parts of the world, has probably seen more species of amphibians and reptiles in their native habitats than anyone else. His background and interests, therefore, are far from being provincial. With these qualifications, and more than three decades of experience in preparing check lists, Mertens, with the able assistance of Wermuth, quite understandably has produced a check list with innovations that will surely be emulated. Notwithstanding such minor errors of omission or interpretation as those mentioned, it is manifest that much time, effort, and attention to detail went into the preparation of *Die*

Amphibien und Reptilien Europas.—C. M. Bogert, *The American Museum of Natural History.*

FISHES OF THE MARSHALL AND MARIANAS ISLANDS. Vol. 2. Families from Mullidae through Stromateidae. By Leonard P. Schultz and collaborators: Wilbert M. Chapman, Ernest A. Lachner, and Loren P. Woods. U. S. National Museum Bulletin 202, vol. 2, 1960, pp. ix + 1–438, pls. 75–123, text figs. 91–123.—U. S. National Museum Bulletin 202 originated with the large fish collections made in connection with the Marshall Island atom-bomb tests of 1946. The first volume appeared in 1953, and the third and final volume is stated to be in preparation. Bulletin 202, when completed, will mark the greatest single advance in scientific knowledge of the fishes of the Central Pacific that has ever been made. The reviewer bases this statement on long, hard use of volume 1, perusal of volume 2, and the assumption that volume 3 of the series will be equally good. However, fair warning should be given that these volumes are for the specialist, not the layman. Thus, there is, at least as yet, no key to the families, and certain of the generic keys, such as that to the parrot fishes, are highly esoteric.

Despite the over all value of the series, it is only with difficulty that one learns to overlook numerous sources of exasperation. These range from the trivial, such as the repeated use of holier-than-thou phrases like "a careful examination" and "precision measurements", to two that are rather important. One of these is the great delay in publication; much of volume 2, for example, was written years ago and many errors have inevitably crept in with the attempt to keep the manuscript up to date. The second important matter concerns coverage, two aspects of which deserve notice. First, there is the very excusable fact that the small and inshore Marshallese fishes were much more adequately collected than the larger and offshore forms; this merely reflects the use of poison as the predominant collecting method. Far more disturbing is the inequality of coverage among the various groups for which extensive material was available. Sometimes a group has been dealt with on a world wide basis, e. g., the genera of Mullidae (the reviewer is heartily in agreement with such treatment wherever possible). At the other extreme, e. g., the Pomacentridae, only the forms represented from the northern Marshall and Marianas Islands have been dealt with (this is logical). But between these extremes is a limbo area of almost capricious coverage. What, for example, is the description of a new genus and species (*Pseudocheilinops ataenia*) from Celebes and the Molluccas [sic] doing in this book? What purpose is served by lifting a key to the genera of scarids of the world from an earlier paper and then providing no key to the species of the area under consideration?

To revert to the credit side, most of the keys in volume 2, if they are up to those of volume 1, will be not only useful but indispensable for identifying fishes anywhere in the Central Pacific (except for Hawaii, which has a large endemic fish fauna). The 48 plates, each with several figures, though of uneven caliber and without indication of the size of the specimen figured, serve both as a means of verifying determinations and as an introduction to Central Pacific fishes for the layman. Indeed, despite obvious faults, it seems most improbable that Bulletin 202 will soon be superseded as a primary reference. In this reviewer's opinion, both the authors and the U. S. National Museum deserve to be congratulated for bringing out volumes so basic to all future study of the inshore fishes of a vast geographic area.—William A. Gosline, *Department of Zoology, University of Hawaii.*

THE SNAKES OF THE SUBFAMILY DIPSADINAE. By James A. Peters. Misc. Pub., Mus. Zool. Univ. Mich. 1960. No. 114, pp. 1–224, plates I–VIII.—Peter's review of the Dipsadinae is to be the first of several growing out of the taxonomic difficulties Peters encountered in his study of Equadorian herpetofauna. The systematics of neotropical colubrids is badly confused, in part because of the difficulties inherent in the group and in part because so much of the previous work has dealt only with restricted geographical areas. Peters' work is an important step towards clearing up the present confusion in a part of this group. Its importance is practical rather than theoretical for it is designed as a guide to the dipsadine snakes rather than a study of them.

This paper should enable anyone to identify almost any dipsadine snake, either in laboratory or field. However, the omission of any description, diagnosis, or characterization of the subfamily may sometimes make it difficult to tell when one has a dipsadine. The paper should enable anyone compiling a faunal list to tell quickly what forms to include and enable a collector or field ecologist to know what dipsadines to expect in any given area. It also provides a guide to the confused nomenclature in the literature.

Peters has used clearly defined external characters in descriptions, keys and in discussing individual and geographic variations. The localities from which Peters examined specimens

are mapped for each species. Complete primary synonymies are given and discussed.

However, certain omissions make the paper less useful than it might have been. Among these are the omission of species names from the table of contents, page references from the keys, and an index. This combination makes it difficult to find information quickly.

Where Peters has synonymized a form or removed one from synonymy he has given his reasons. But he has omitted the reasons for his taxonomic decisions at other levels. He has (p. 5) "inquired into their [the Dipsadinae] relationships to amblycephalid species of Asia." He reports (p. 13) the results of this inquiry only in the statement that "the Dipsadinae is considered to be entirely Neotropical, and this requires that *Amblycephalus* and *Aplopeltura* be removed from Amaral's list and replaced in the Asiatic family Amblycephalidae."

Peters states (p. 14) that, historically, the problems in defining the Dipsadinae arose from "the persistence of intermediate forms." Though he has obviously defined the subfamily for himself, he never gives his definition nor does he discuss the intermediate forms and his reasons for including or excluding them.

Peters states that the characters distinguishing the Dipsadinae are the results of two different adaptive trends, one well developed in the genus *Sibon*, the other in *Sibonomorphis* and that both are well developed only in some of the species of *Dipsas*. However, the possibility of a polyphyletic origin of the subfamily is not even mentioned.

The use of color pattern as a primary basis for dividing genera into species groups is unusual in snake taxonomy. Color pattern is subject to geographical and individual variation in many colubrids and even in some species of the Dipsadinae. Still, Peters uses color pattern as the basis of his species groups in both *Dipsas* and *Sibon* without explaining why or without any explicit discussion of other characters that support his groupings.

Peters places *longicaudata*, in the *polylepis* group of *Dipsas*, despite grooved rear teeth and a mental groove, neither of which occur in any other member of the genus. In discussing this species (p. 95) his only statement is "Because of the possibility that it legitimately deserves a place in this species group, I retain it here rather than allow an available name to vanish into the synonymy of a species [*Siphlophis cervinus*] to which it almost certainly cannot belong."

Peters explains (p. 97) that the removal of *leucomelas*, described from Columbia, from the genus *Tropidodipsas* "is primarily based on the geographical provenance, for that genus (as currently defined) does not extend farther south than Honduras." No reference is given to this definition of *Tropidodipsas* and I am unable to find it. But after saying (p. 98) "Obviously current information is insufficient to assign definitely the species to any genus", he does not even explain why he assigned it to this subfamily, much less this genus.

Peters removes *carri* from *Tropidodipsas* and places it in *Sibon* without comment either under the species or under the genus. Unlike *leucomelas*, mentioned above, this decision cannot be based on geographic grounds since *carri* was described from Honduras.

Peters has examined a great many specimens and all the available literature and given considerable thought to these taxonomic decisions. He undoubtedly had reasons for these decisions but these reasons should be presented. Taxonomic changes by fiat may sometimes be unavoidable in checklists but not in revisionary studies such as this one.

Peters writes (p. 14) that "The subfamily provides an interesting study for the evolutionist." It is obvious that this paper is not and was never intended to be such a study.

All discussion of speciation and zoogeography has been omitted. No phylogenies are attempted and there is no discussion of the relationships of this subfamily to the other colubrids. Indeed, the only considerations of any theoretical problems come in a four and one-half page section called "Evolutionary Trends." Here he advances some very interesting ideas but only in very general terms with infrequent references to individual species. Unfortunately he also omits any mention of most of the characters involved in these trends from his species descriptions so that his statements can neither be amplified nor checked. This same section also includes all the information given on ecology (other than an occasional mention that a species occurs in a particular ecological association), behavior, and functional morphology. Even his own observations on the several species he has seen alive are omitted.

This paper, though of value to anyone working on the subfamily Dipsadinae, is only a first step in exploiting the general interest and theoretical importance of the study of these snakes. Let us hope that Peters will advance this study to the next and more interesting stage.—A. STANLEY RAND, *Harvard University, Cambridge, Mass.*

Editorial Notes and News

Cumulative Catalogue

THE American Society of Ichthyologists and Herpetologists announces the preparation of a new edition of the Society-sponsored Cumulative Catalogue of American Amphibians and Reptiles. The new cumulative catalogue will have a completely revised format with greater detail than any previous edition, will be a loose-leaf publication, and will be authored by many specialists. As the need for revision arises, new individual pages will be published to supplant the original ones. The preparation of the new catalogue is under the guidance of a checklist committee. The chairman and editor is William J. Riemer, *Florida State Museum, Flint Hall, University of Florida, Gainesville.*

Congress of Limnology

THE XVth International Congress of Limnology will be held at the University of Wisconsin, Madison, Wisconsin, 20–25 August 1962. The Congress is sponsored in North America by the American Society of Limnology and Oceanography with the cosponsorship of the National Academy of Sciences–National Research Council and the International Society of Theoretical and Applied Limnology. All previous congresses held triennually, have been in Europe. Inquiries should be addressed to: *The XVth International Congress of Limnology,* % Dr. John C. Wright, *Birge Hall, University of Wisconsin, Madison 6, Wisconsin.*

Sessions on the world's great lakes, latitudinal limnology, decomposition, and problems common to limnology and oceanography are among those planned. Excursions are scheduled for participants to various aquatic areas and research centers of North America. The Executive Committee for the Congress is: Drs. Arthur D. Hasler, *Chairman,* John C. Wright, *Executive Secretary,* George H. Lauff, *Treasurer,* Kenneth D. Carlander, David G. Frey, and Donald S. Rawson.

Pacific Science

THE 10th Pacific Science Congress of the Pacific Science Association will be held at the University of Hawaii, Honolulu, from 21 August to 6 September 1961, under the sponsorship of the U. S. National Academy of Sciences and the Bernice P. Bishop Museum, with the cooperation of the University of Hawaii. Scientific sessions will be held from 21 August to 2 September, to be followed by a field trip that will continue through 6 September.

This congress will include a Section of Science Information, with Burton W. Adkinson as section organizer. Adkinson is head of the Office of Science Information Service, National Science Foundation, Washington 25, D. C. Science information will be discussed in terms of improving scientific communication and documentation practices between countries in the Pacific Ocean area.

Marine Stations in Baja, California

WITH support from The National Science Foundation The San Diego Society of Natural History has established and is operating the Vermilion Sea Field Station, on Bahia de Los Ángeles, Baja California Norte. This station is in an almost virgin area, for both terrestrial and marine life. The bay is speckled with small islands, lying inside the large Isla Ángel de la Guarda, and other islands, rich in fish life and with considerable endemism in the reptiles and in other terrestrial ilfe, lie nearby. Facilities are available for both land and sea transportation. Inquiries may be directed to Dr. George E. Lindsay, *Director, San Diego Museum of Natural History, Balboa Park, San Diego, California.*

The newly organized Universidad de Baja California (at Mexicali) has established a Centro de las Investigaciones Marinas, to be located at Ensenada under the directorship of Señor Pedro Mercado Sánchez, who has been on the staff of the *Dirección General de Pesca e Industrias Conexas.*

University News

University of Colorado.—Dr. T. Paul Maslin has an N.S.F. grant to investigate the all-female species of the genus *Cnemidophorus* especially *Cnemidophorus deppi cozumelus* on Cozumel Island, near Yucatan, Quintana Roo, Mexico and to study the breeding of *Cnemidophorus tessellatus.* Mr. Clarence J. McCoy, Jr., M.S., Oklahoma State University, is continuing his work on the Ph.D. degree studying the life history of *Cnemidophorus tigris septentrionalis* at Colorado National Monument with the support of the U. S. Park Service. Mrs. Kathleen Beargie is studying the comparative osteology

of the skulls of Cnemidophorus and would appreciate assistance in obtaining skeletal material.

University of Illinois.—Projects in progress by students in the Department of Zoology, University of Illinois, in systematics, anatomy and physiology of fishes, amphibians and reptiles, include: (a) Osteology and phylogeny of anabantid fishes, KAREL LIEM. (b) Anatomy of the symbranchoid eel, *Fluta alba*, KAREL LIEM. (c) Systematics of *Gyrinophilus*, RONALD BRANDON. (d) Osteological evidence bearing on the generic status of the species of alligator lizards sometimes referred to the genera *Elgaria, Barisia* and *Gerrhonotus*, BRUCE CRILEY. (e) Systematics of *Cnemidophorus inornatus*, KENNETH WILLIAMS. (f) Herpetofauna of Aguascalientes, Mexico, KENNETH WILLIAMS. (g) Systematics of *Sceloporus jarrovi*, PETE CHRAPLIWY. (h) Systematics of American pelobatid toads, PETE CHRAPLIWY. (i) Osteological evidence bearing upon the generic status of the collared and leopard lizards, NANCY FORSYTH. (j) Effect of *Crotalus atrox* venom upon mammalian blood as a means of assay of degree of venom intoxication, RONALD FRUGE. (k) Physiology of ophidian viviparity, THOMAS BETZ. (l) Comparative osteology of *Cnemidophorus*, KENNETH WILLIAMS.

University of Southern California.—The Department of Biology of the University of Southern California announces an Advanced Biology Institute For Junior College, College and University Instructors entitled—*Fundamentals of Tropical Biology: An Ecological Approach*. The Institute is sponsored by the National Science Foundation and will be held in Costa Rica, with the cooperation of the Universidad de Costa Rica, July3–August 11, 1961. The program will center at the Universidad in San José, but will include 10 days of field work and instruction in all major tropical habitats within the country. Principal sections of the Institute are as follows: The Tropical Environment, The Tropical Biota, Ecologic Relations and Dynamics, and Evolution in the Tropics. All instruction will be given in English by the Institute directors and a team of Costa Rican biologists selected for their special knowledge. The program is under the direction of DR. J. M. SAVAGE and DR. ANDREW STARRETT of the University of Southern California and DR. RAFAEL L. RODRÍGUEZ of the Universidad de Costa Rica. The Institute is open to any teacher of biological sciences, without previous tropical experience. The program is not limited to the field biologists. Participants in the Institute will receive travel expenses and a per diem allowance while in Costa Rica. Application Forms and additional information may be obtained by writing: DR. JAY M. SAVAGE, *Director Summer Institute, Department of Biology, University of Southern California, Los Angeles 7, California.*

Tulane University.—DR. FRED R. CAGLE has relinquished his post as Chairman of the Zoology Department, having been elevated to a newly created office of "Coordinator of Research". In this new capacity his role is "to insure the full development of each scholar's potentialities, to enhance the academic atmosphere of research, to assist applicants in seeking research grants, and to serve as liason officer with research bodies and granting agencies". In addition to these activities DR. CAGLE continues his investigations of the systematics of *Graptemys*.

DR. E. PETER VOLPE is continuing his investigations of the systematics and genetics of Anura under NSF sponsorship. He has recently been promoted to the rank of full professor.

DR. ROYAL D. SUTTKUS, recently promoted to full professor, is conducting two major sponsored investigations: a study of garfish systematics with a grant from NSF, and a prepollution study of fishes of the Pearl River system with support from NIH.

DR. HAROLD A. DUNDEE has been elevated to the rank of assistant professor and has been appointed curator of the herpetological collections. He is currently engaged in researches on neoteny in salamanders under NIH sponsorship.

DR. GERALD GUNNING is now an assistant professor and is conducting studies on home range and homing behavior of sunfishes with grants from NIH, NSF, and the Sports Fishing Institute.

Recently completed theses include: B. I. SUNDARARAJ, Ph.D., "Age and growth of the spot, *Leiostomus xanthurus*"; C. ROBERT SHOOP, M.S., "Breeding habits of the mole salamander, *Ambystoma talpoideum*, in Southeastern Louisiana"; JAMES DOBIE, M.S., "Growth in *Diadophis punctatus stictogenus*"; SUE HARVEY, M.S., "The mouthparts of *Scaphiopus h. holbrooki*"; IAN D. W. SUTHERLAND, M.S., "Renal function of watersnakes". Doctoral dissertations now underway include C. ROBERT SHOOP on population dynamics and home range of *Necturus*; JAMES DOBIE on biology of the loggerhead turtle, *Macroclemmys temminckii*. Working on the master's degree are MYRNA ANDERSSON WILKENS on systematics of the spotted sunfish, *Lepomis punctatus*; JOHN RAMSEY on Central American cichlids; SARAH EBERSOLE on anatomy of salamander spermathecae; and BARBARA TAYLOR on sequence of morphological changes during induced metamorphosis in salamanders.

DR. B. I. SUNDARARAJ remains as research associate in fishery biology and currently is working on seasonal changes in the gonad of the men-

haden and on seasonal changes in the speckled trout, *Cynoscion nebulosus*.

Some recent boosts to research activity have been received with the procurement of two new International Travelall station wagons and two new pickup trucks for field work, and the installation of fiberglass-lined wooden tanks for storage of large herpetological specimens.

Copies of A. H. WRIGHT's "Herpetological Terminology" are still available upon request to DR. HAROLD A. DUNDEE, *Zoology Department, Tulane University, New Orleans 18, Louisiana*. Microcards of several major out-of-print works are still available from the Department of Zoology at Tulane.

DR. A. T. DE ROCHEBRUNE, Vertebratorum novorum vel minus cognitorum orae africae occidentalis incolarum, 1883–1886, 2 cards; .50.

EGID. SCHREIBER, Herpetologia Europaea. Eine systematische Beareitung der Amphibien und Reptilien, welche visher in Europa aufgefunden sind, 1912, 22 cards; 5.00.

Reprints, Collected by U. S. National Museum. Reptiles and Batrachians, I: General (1831–1877) Vol. 41, 22 cards; II: Tortoises & Lizards (1829–1876) Vol. 42, 17 cards; III: Serpents (1816–1874) Vol. 43, 21 cards; IV: Batrachians (1831–1877), Vol. 44, 17 cards; Total, $19.00.

GEORGE ALBERT BOULENGER, 1858, Catalogue of the Snakes in the British Museum (Natural History), v.1, 1893, 8 cards v.2, 1894, 8 cards v.3, 1896, 15 cards. Catalogue of the Chelonians, Rhynchocephalians, and Crocodiles in the British Museum (Natural History) 1889, 7 cards. Catalogue of the Batrachia Gradienta s. Caudata and Batrachia Apoda in the Collection of the British Museum. 1882, 3 cards Catalogue of the Batrachia Salientia s. Ecaudata in the Collection of the British Museum, 1882, 11 cards. Catalogue of the Lizards in the British Museum (Natural History) London, 10 cards. Catalogue of the Lizards in the British Museum (Natural History) London, 11 cards. Catalogue of the Lizards in the British Museum (Natural History) London v.3, 1887, 13 cards; Total, $20.00.

News Notes

DR. HENRY B. BIGELOW, research oceanographer at the Museum of Comparative Zoology at Harvard, is the first recipient of the HENRY BRYANT BIGELOW Medal for oceanography which was recently established by the Woods Hole Oceanographic Institution. DR. BIGELOW was one of the Institution's founders and its first director.

PROFESSOR TH. MONOD, Laboratoires des Peches Outre-Mer, Museum d'Histoire Naturelle, 57, rue Cuvier, Paris 5e, would be glad to receive specimens of the extremities of spines (the last 10 vertebrae if possible, or failing this, the last 7 or even the urophore complex only) of the main species of Thunnidae (sensu lato) and Scombridae; this material should be sent dry, the flesh being removed or not; the dermic rays of the caudal fin may be cut at the level of the fork.

DR. J. CADENAT, IFAN-Biologie Marine, Goree, Senegal, would like to obtain elasmobranch material, especially dried jaws of skates and rays and dried jaws and dried skin samples of sharks. He has no material from the Pacific so the jaws of any species will be helpful.

DR. BRIAN CURTIS of St. Helena, California, Chief Biologist of the California Department of Fish and Game, died suddenly on September 5, 1960. He is well-known for his work with G. K. NOBLE on the social behavior of the jewelfish, and for his extensive studies of the golden trout and other fresh water fishes of California. He conducted several significant studies in the field of fish management, and was the author of the popular and accurate "The Life Story of the Fish," published in 1938 and in 1949, and translated into Swedish, Italian and Dutch.

DR. PETER O. OKKELBERG, former Professor of Zoology and Associate Dean of the Graduate School of the University of Michigan, died on September 13, 1960. He was known to ichthyologists for his work on the development and life history of lampreys.

DR. JAMES E. MORROW, JR., Research Associate in the Bingham Oceanographic Laboratory at Yale, has been appointed Associate Professor of Fisheries in the Department of Wildlife Management at the University of Alaska, College, Alaska. DR. MORROW begins his new duties in September.

DR. CHARLES J. FISH, Director of the Narragansett Marine Laboratory of the University of Rhode Island announces the dedication on October 8, 1960 of a new building to replace one destroyed by fire.

DR. SEBASTIÁN A. GUARRERA, dean of the faculty of natural sciences and of Museo La Plata, Argentina, announces that on December 11 last the first marine biological station in Argentina was created at Mar del Plata.

The Oregon Herpetological Society met September 10 and 11 at House Rock Forest Camp on the South Santiam River, and again on January 11 at Oregon State College, Corvallis, Oregon.

DR. RICHARD ETHERIDGE joins the staff at San Diego State College in September, 1961.

Southern California Herpetologists met January 7, 1961 at the University of Southern Cali-

fornia for an informal get-together. A general discussion of research activities preceded lunch and the afternoon was spent in small group conferences. Dr. L. M. Klauber discussed his early experiences collecting with Van Denburgh and Slevin. Hosts included Dr. Jay M. Savage, Dr. Richard Etheridge, Mrs. Priscilla Starrett, David B. Wake, Arden H. Brame, Jr., Arnold Kluge, Anthony J. Gaudin, James L. Vial. In attendance were Dr. Richard A. Pimental, Cal. Poly; Dr. Richard Loomis, Julius C. Guest, Kenneth D. Peyton, Long Beach State; R. C. Stephens, El Camino College; Dr. James A. Peters, San Fernando Valley State; Dr. Bayard H. Brattstrom, Orange County State; Dr. Donald Hunsaker, Dr. D. L. Jameson, James Conley, Michael H. Smith, Patricia Goset, Lynette Rath, San Diego State; Charles E. Shaw, San Diego Zoo; Dr. L. M. Klauber, San Diego Natural History Museum.

Following the ASIH meeting in Austin, on April 3, 1961, Carl L. Hubbs, Robert Rush Miller, and W. L. Minckley and botanist Donald R. Tindall (graduate students from the University of Louisville) spent 8 days investigating the hydrology, ecology, Characeae, and largely endemic fish fauna of the rather isolated Cuatro Ciénegas basin of Coahuila, México. The three ichthyologists are collaborating in an intensive study of the origin and evolution of the fishes; more than 40 collections from within and just outside of the basin, covering a span of 22 years, are now available for this undertaking, and several taxonomic papers are in press or nearing completion.

Mr. Bert N. Kobayashi, graduate student in ichthyology at the Scripps Institution of Oceanography, has been granted a Community Scholarship from Hawaii for 1961–1962.

Dr. T. C. Roughley, well known Australian naturalist, died January 14, 1961, at "Tuggeruh Lakes Resort". Before his retirement from government service some years ago he authored technical and popular publications on Australian fishes and fisheries and on the biology of the Great Barrier Reef.

The Karl P. Schmidt Fund has modest sums available to asist persons wishing to study at the Chicago Natural History Museum. Grants will be made for study in any of the four fields encompassed by the museum: anthropology (with a natural history orientation), botany, geology (including paleontology), and zoology. An applicant should describe the study proposed in brief terms, state the length of time he wishes to study at the museum and the amount of money needed, and name one reference.

Applications should be mailed to: Chairman, The Karl P. Schmidt Fund, c/o Chicago Natural History Museum, Roosevelt Road and Lake Shore Drive, Chicago 5, Illinois.

MARGARET HAMILTON STOREY

(1900–1960)

MARGARET Storey, Stanford's well known ichthyologist, and President of the Western Division of the A.S.I.H. in 1941–42, passed away in October 1960. She was born in San Francisco on the 31st of July, 1900. She was the eldest of the three daughters of Thomas Andrew Storey and his wife, née Parnie Olive Hamilton. Margaret's father grew up in Gold City, Nevada, and her mother in California; both graduated from Stanford University. The family moved to New York in 1904, but later returned when Thomas Storey founded (and, for a number of years, directed) Stanford's Department of Health and Athletics. This, and the fact that both her sisters became M.D.'s, gave Margaret an abiding side-interest in both medical matters and athletics.

Margaret Storey in the Stanford Natural History Museum, 10/52 Photo by R. S. Ferris.

Margaret obtained her A.B. degree at Cornell University in 1922. For several years thereafter, she worked in the theatrical world as stage manager of a number of plays, and this experience was of great value to her in later years. Whenever she was a member of the organizing committee for a scientific meeting or event, every detail was as completely thought out, planned, and timed as are the entrances and action in a play and, unless her co-workers failed to follow her explicit directions, the event went off like clockwork.

In the late 1920's and early 1930's, Margaret spent a good deal of time at Sanibel Island, on the west coast of Florida, where she was closely

associated with Louise M. Perry in studies of the marvellous molluscan fauna of the Gulf of Mexico. It was apparently at Sanibel that Margaret became interested in fishes and her first papers date from that period. From 1932 to 1935, as Assistant in Bibliography in the Bashford Dean Library in the American Museum of Natural History, Miss Storey assisted the late Dr. E. W. Gudger in compiling the still-unpublished continuation of Dean's "Bibliography of Fishes." In this work she became a highly able bibliographer and librarian; these skills were also called into use in later years.

In 1935, Margaret rejoined her family in California. She quickly completed her A.M. degree under Prof. W. H. Rich (granted 1936) and continued to act as a volunteer researcher and assistant in the Stanford Natural History Museum (to which I returned late in 1936) until 1940. Margaret's skills, energy, and enthusiasm were so great that I soon began to urge that she receive a regular staff appointment. This was finally done in 1940, and from that day until her death she held the post of Assistant Curator of Zoological Collections in the Museum.

Margaret soon became the busiest and most useful person in the zoological division. She acted not only as curator, but also as librarian of the growing zoological library, and editor of "Stanford Ichthyological Bulletin" and our "Occasional Papers," but also as counsellor and helpful assistant to everybody—faculty, graduate students and visiting investigators alike. In this work neither she nor I had more than occasional secretarial aid for several years, and never more than the half-time help of one student assistant.

Margaret's research was done mostly before she became a staff member. After that she was too busy. While I was away during the war (1942–1944) she was effectively in charge of zoological collections, and after the war, as students increased in numbers, and the collections, library, and Museum business became greater, the work of the staff became doubled and then quadrupled, but the heaviest burden fell on her. Despite it all, she remained cheerful, and every one of the ichthyological and herpetological graduate students at Stanford, from 1936 to her death, will remember her as a tower of strength and help.

Margaret Storey was no scientific drudge. She was a first-class researcher, as her publications testify. However, she had a life of her own, quite aside from the Museum. Her interest in athletics, especially track, took her to an increasing number of intercollegiate contests, until she became an unofficial, and later an officially appointed timer of track events, the only woman so qualified. She also loved the open air, travel, and biological field work, and she made many long trips throughout the United States, seldom returning without specimens for the Museum. She served as Secretary of the Western Division of the A.S.I.H. from June 1937 until her election to the presidency of the Division for the year 1941–1942. She was also active in the Western Society of Naturalists.

During the last few years Margaret suffered from a lung ailment which caused her increasing difficulty. In the Spring and Summer of 1960, while I was away in Europe, she labored on the preparation of a large issue of the Ichthyological Bulletin, despite her illness. She entered Children's Hospital, in San Francisco, at the beginning of October, for surgery, but did not survive. She passed away in the hospital on October 18th.

Margaret Storey's passing ends a whole chapter of ichthyological work in California. Although she published comparatively little, few people have ever done so much to further ichthyology, herpetology and zoology; she constantly sacrificed her interests to those of others. She was probably one of the ablest curators of a large zoological research collection in the world. Almost every active American ichthyologist and herpetologist of the past 25 years owes much to her.

Margaret is survived by two sisters, Parnie (Mrs. Albert Waldo Snoke) and Marion (Mrs. George Lowell Emerson).

G. S. MYERS

PUBLICATIONS OF M. H. STOREY

1933. (WITH LOUISE M. PERRY.) A record of young tarpon at Sanibel Island, Lee County, Florida. *Science, 78:284.*

1936. (WITH E. W. GUDGER.) Mortality of fishes due to cold at Sanibel Island, Florida. *Ecology, 17:640–8.*

1938. The relation between normal range and mortality of fishes due to cold at Sanibel Island, Florida. *Ibid., 18:10–26.*

1938. West Indian clupeoid fishes of the genus *Harengula* with notes on *H. thrissina* from the Pacific Coast. *Stanford Ichth. Bull., 1:3–56.*

1939. Contributions towards a revision of the ophichthyid eels. I. The genera *Callechelys* and *Bascanichthys*, with descriptions of new species and notes on *Myrichthys*. *Ibid., 1:61–84.*

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